Aligning HERS Index Values With Code Requirements: Properly Assessing Windows

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Poor Excuse…

First, Some Basic Window Performance Background…

How Do We Pick a Window?

- Aesthetics
- Cost
- Heat Loss
- Heat Gain
- Air Leakage
- Water Penetration
- Wind Load Resistance
- Sound Transmission
- Fabric Fading Potential
- Condensation Resistance
- Visible Light Transmission
- Daylighting
- Ventilation Efficiency
- Operating Characteristics
- Maintenance & Durability
- Code Compliance
- Warranty Considerations
- Other Issues…

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- Visib nsmission
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- Maintenance & Durability
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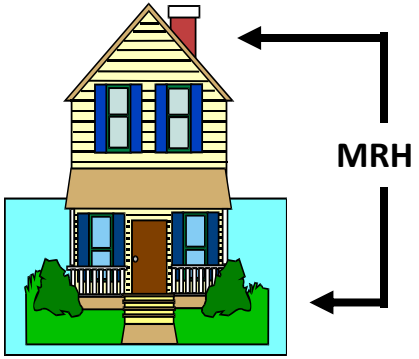
What does the CODE require?

Design Pressure Elements

Wind Speed

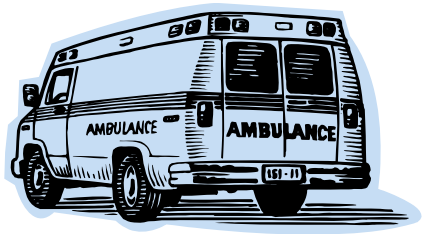
Unit Size



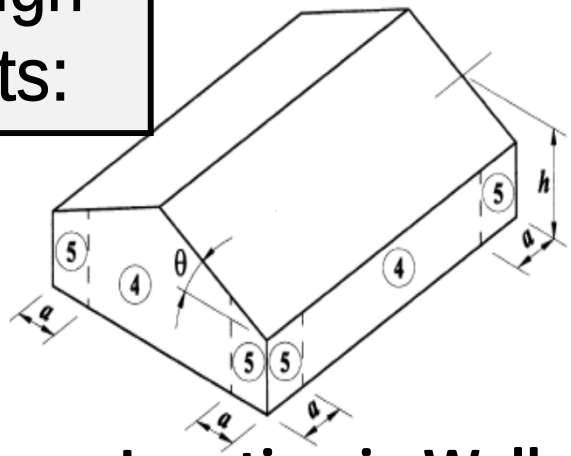
Mean Roof Height

Exposure

Six basic elements are used to calculate design pressure requirements:

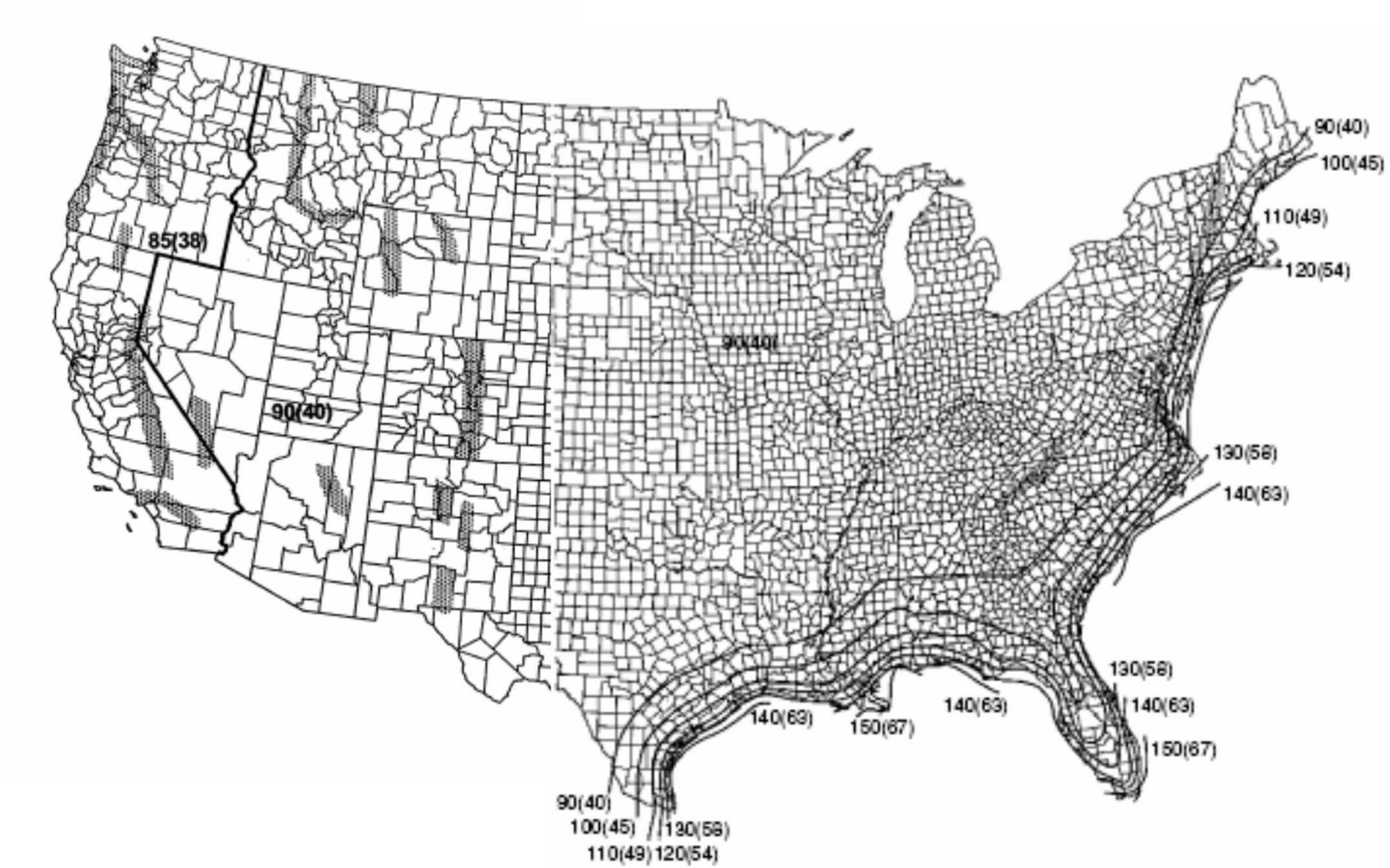


Importance factor



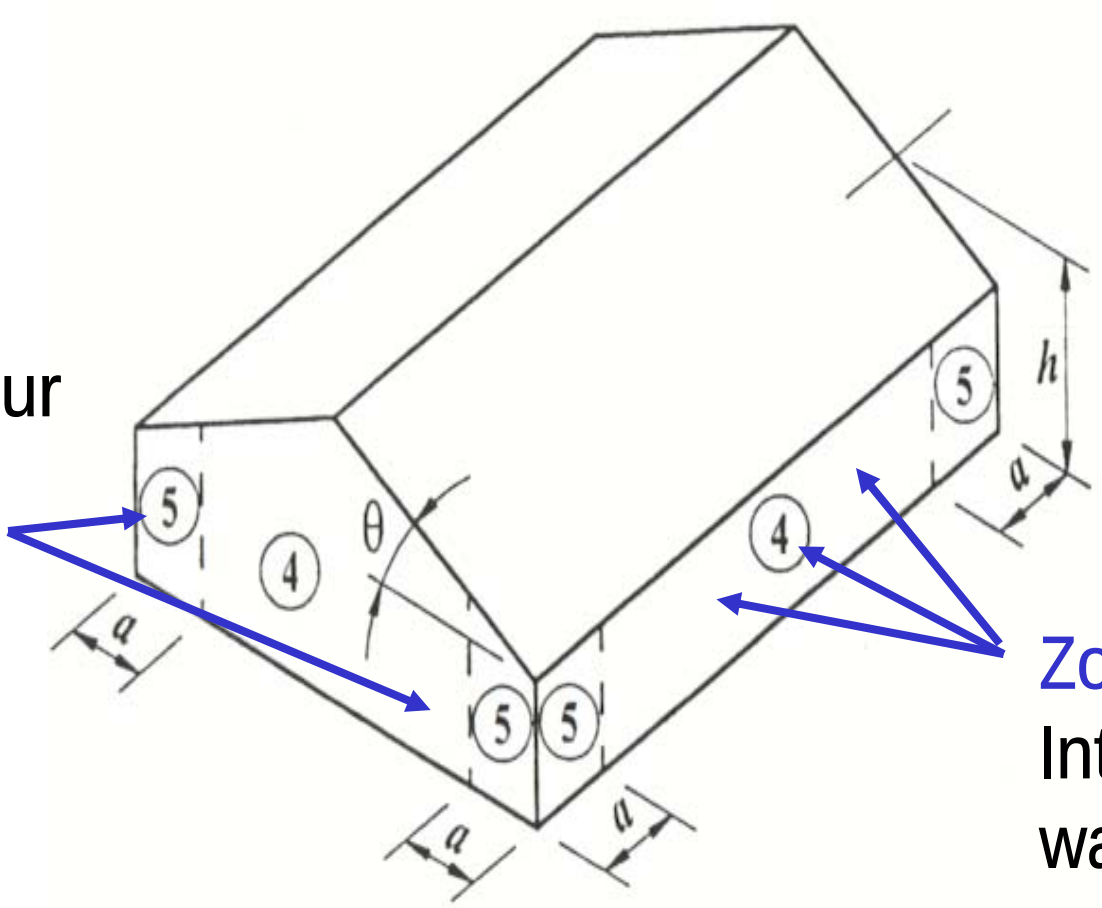
Location in Wall

Know Your Wind Speed!



Know Where **&** What Size

Zone 5
Within four feet of a corner



Zone 4
Interior wall area

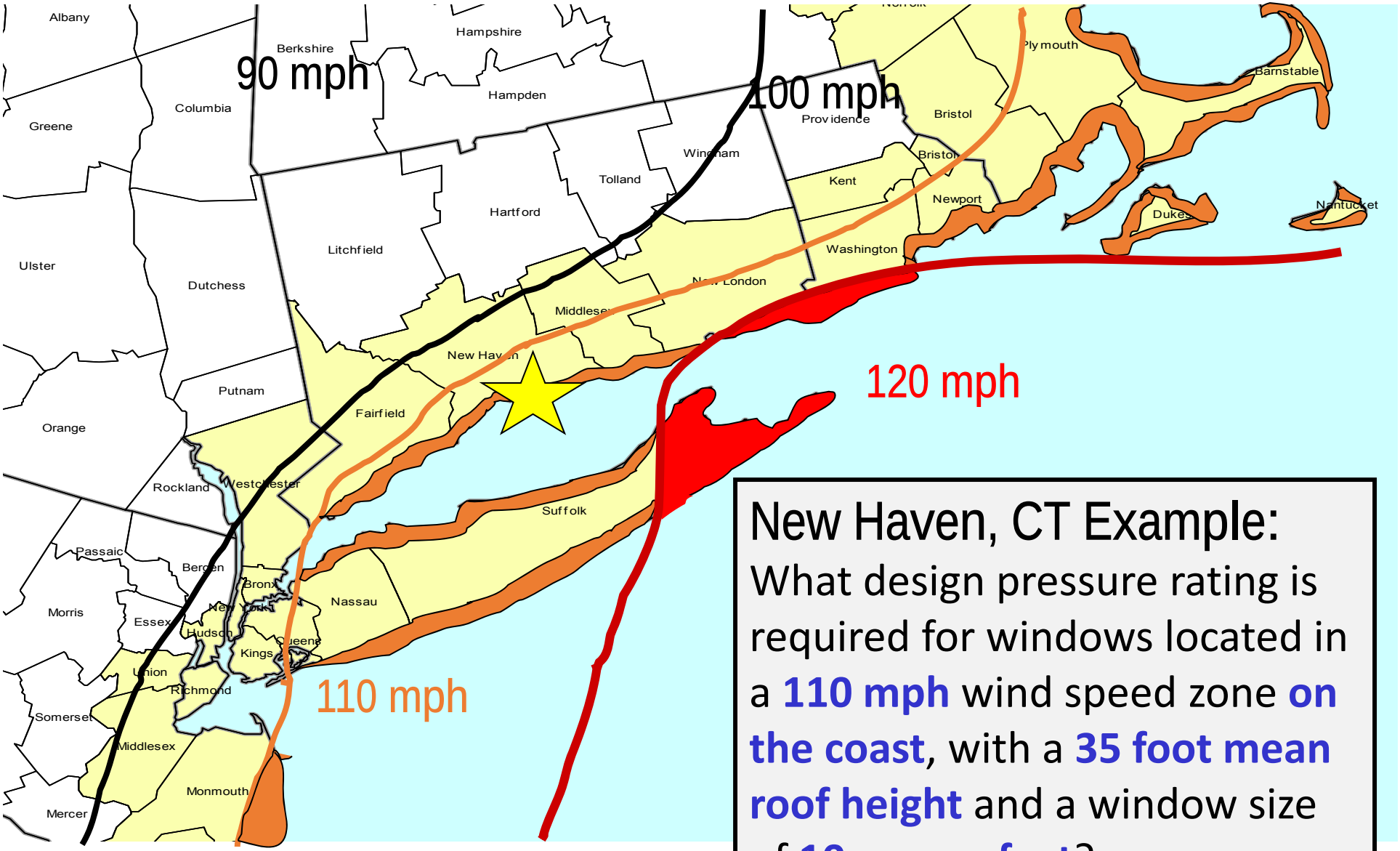
Know Your Exposure

Exposure B

Areas with numerous closely spaced obstructions such as trees and houses

Exposure C

Areas with scattered obstructions such as a coast line or open land



New Haven, CT Example:

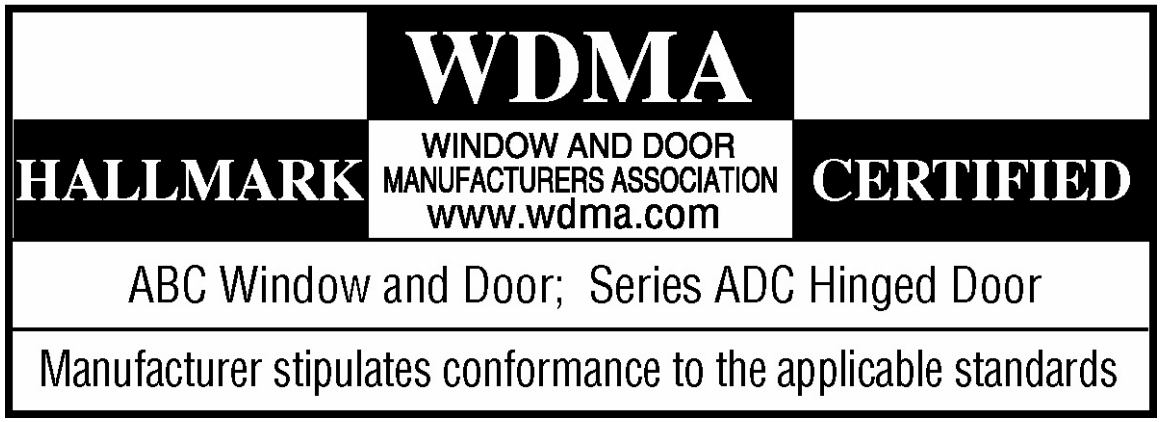
What design pressure rating is required for windows located in a **110 mph** wind speed zone **on the coast**, with a **35 foot mean roof height** and a window size of **10 square feet**?

Certification Required by Code

R613.4 Testing and labeling. Exterior windows and sliding doors shall be tested by an approved independent laboratory, and bear a label identifying manufacturer, performance characteristics and approved inspection agency to indicate compliance with AAMA/WDMA/CSA 101/I.S.2/A440.

Source: IRC 2006

Certification Examples



Now, let’s talk about Windows and Energy

Energy Performance Basics

- U-factor
- Solar Heat Gain Coefficient

- Visible Transmittance
- Air Leakage

Historical Energy Improvement Options

- Add more layers of glass
  - Single, double, triple, etc.
  - Better insulating values
- Change frame materials
  - Move from metals to less conductive materials
    - Thermal breaks, wood, vinyl, fiberglass, composites
  - Move from aluminum to warm-edge spacers
- Add tinted or reflective glass
  - Absorb sunlight with tinted glass
  - Reject sunlight with reflective glass

The Rule of Panes

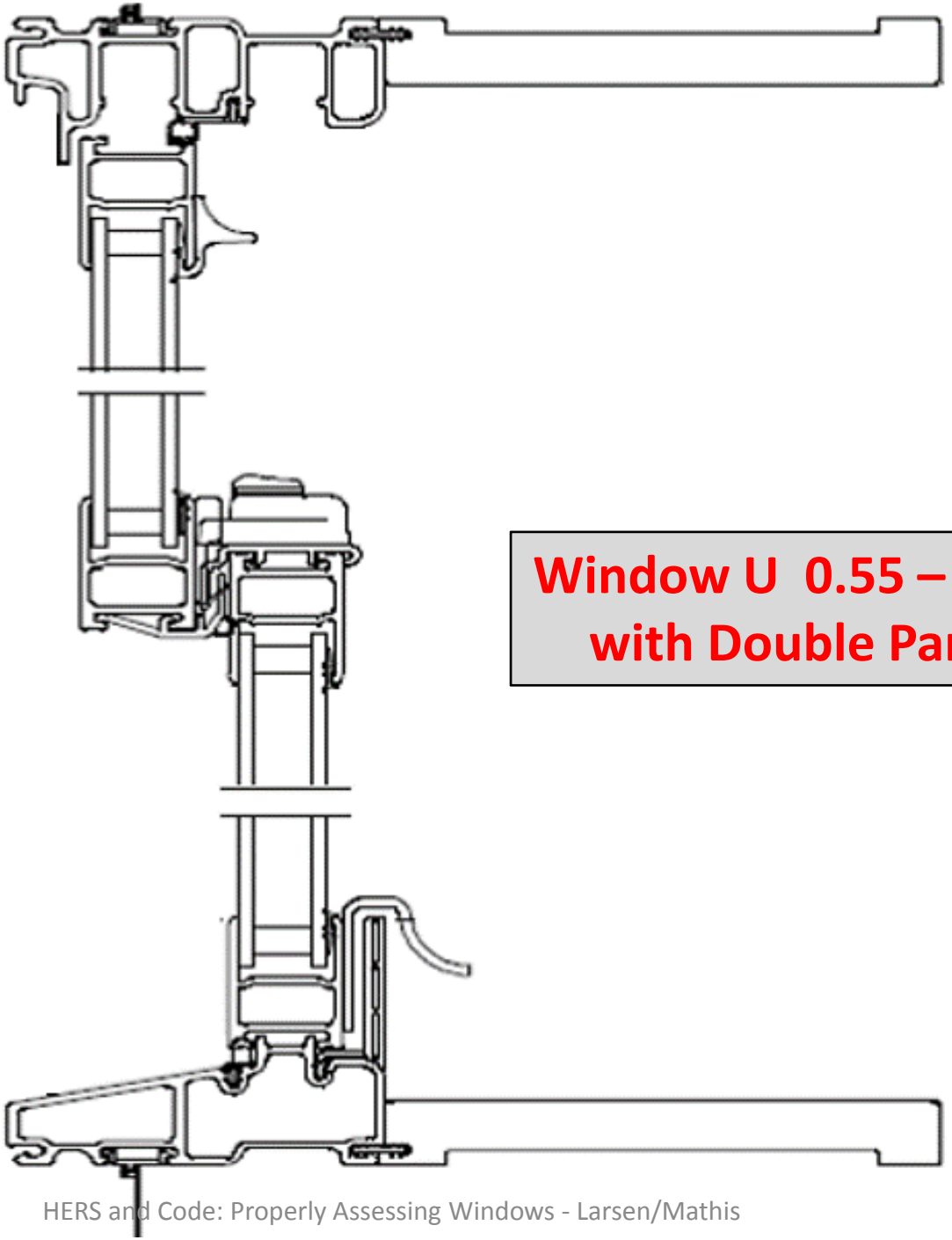
- Single Pane ~ R1 *

*NOTE: Energy codes rate windows in terms of U-Factor. The use of R-Value here is illustrative for glass only (component) ranking.

The Rule of Panes

- Single Pane ~ R1
- Double Pane ~ R2

  (single + storm, or dual pane insulating glass)



Window U 0.55 – 0.80 with Double Pane

Default Table in the Code…

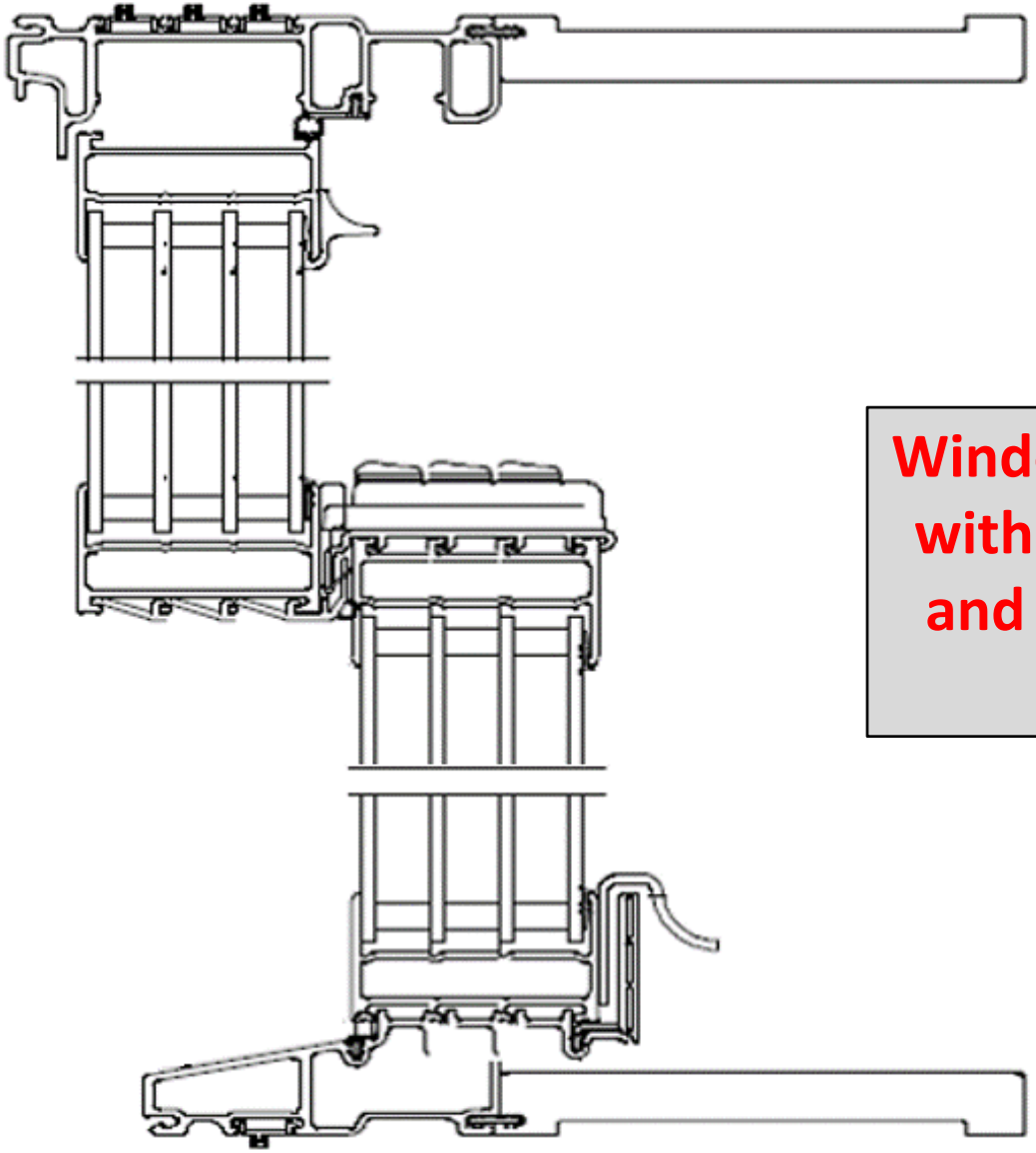
TABLE R303.1.3(1)
DEFAULT GLAZED FENESTRATION *U*-FACTOR

FRAME TYPE	SINGLE PANE	DOUBLE PANE	SKYLIGHT	
			Single	Double
Metal	1.20	0.80	2.00	1.30
Metal with Thermal Break	1.10	0.65	1.90	1.10
Nonmetal or Metal Clad	0.95	0.55	1.75	1.05
Glazed Block	0.60			

More Panes?

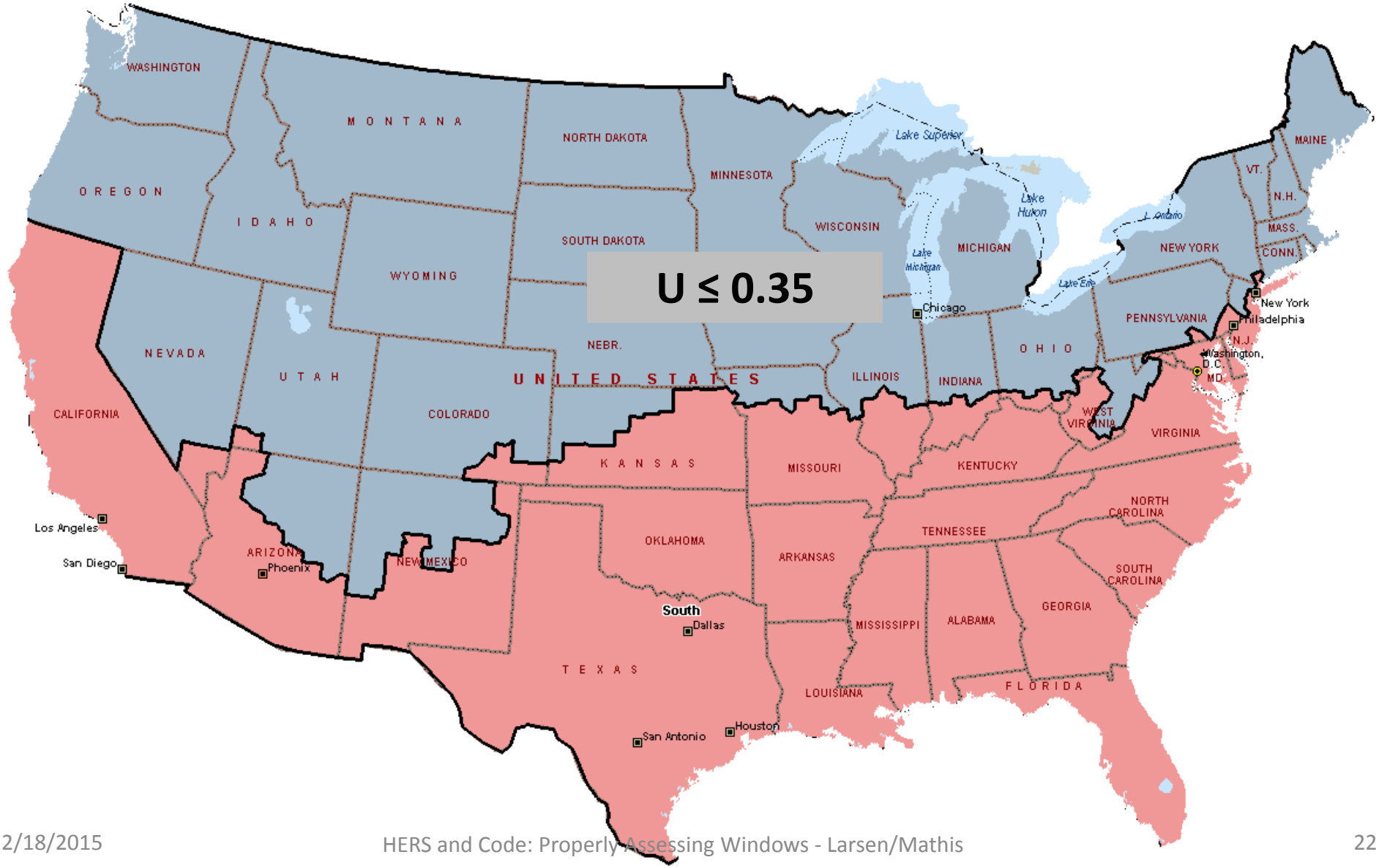
- Single Pane ~ R1
- Double Pane ~ R2
- Triple Pane ~ R3
- Quad Pane ~ R4

Too Much Pain?



Window U ~ 0.35 with Quad Pane and Non-Metal Frame

Code = “Quad” Performance in North

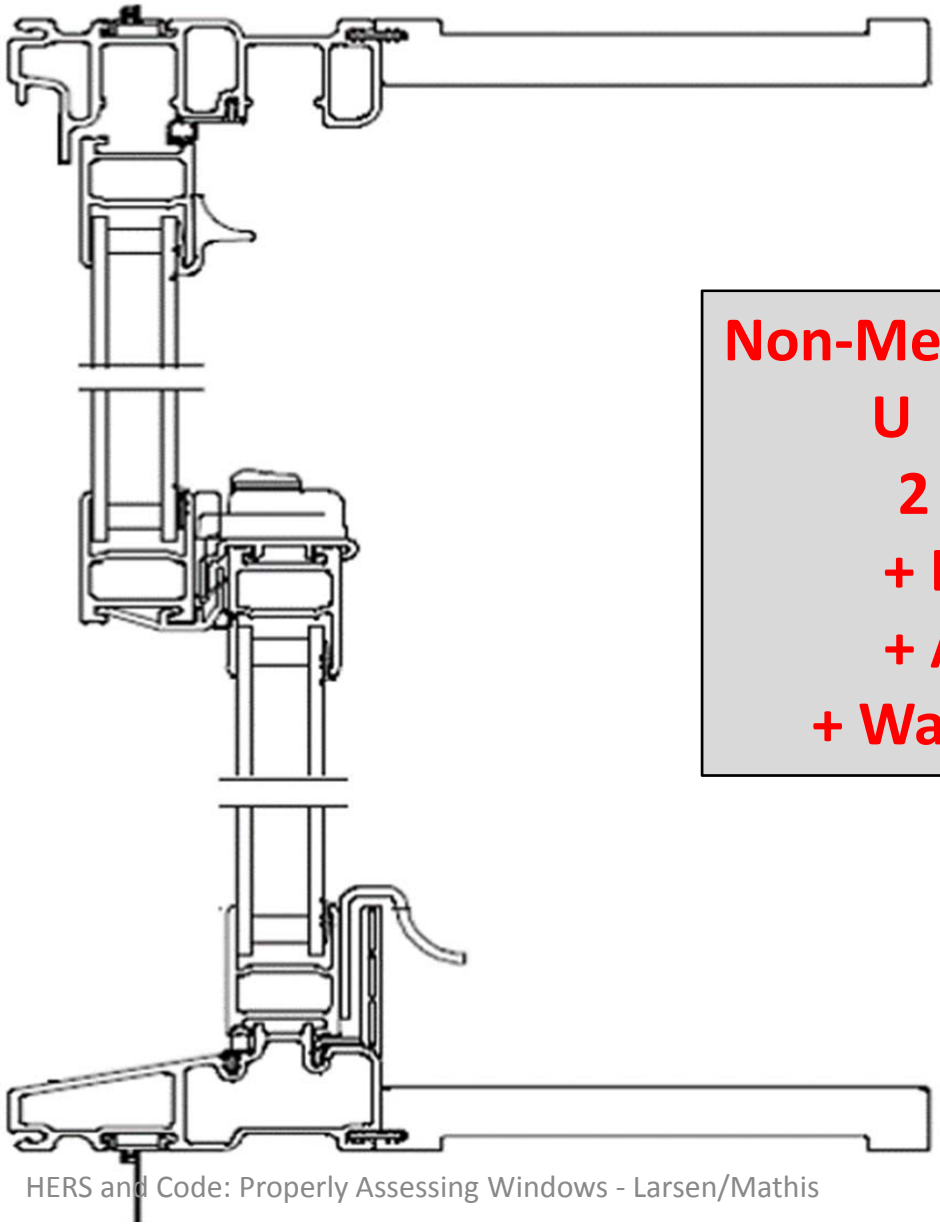


Less Panes with Low-E

- Single Pane ~ R1
- Double Pane ~ R2
- Triple Pane ~ R3
- Quad Pane ~ R4

- 2 Pane + Low-E ~ R3
- 2P + Low-E + Argon ~ R4

Quad Performance With 2 Panes



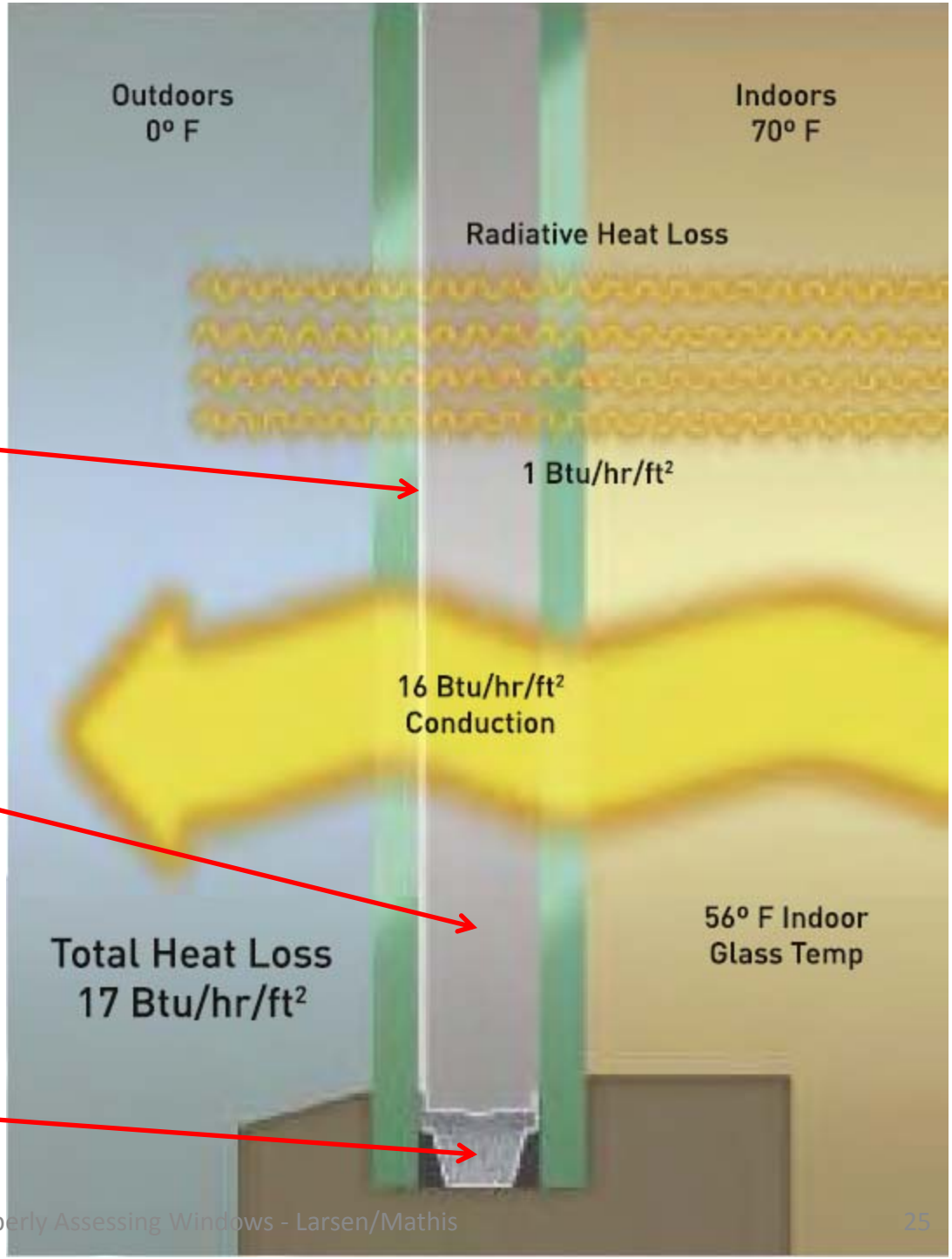
Non-Metal Window
U ~ 0.30
2 Pane
+ Low-E
+ Argon
+ Warm Edge

Quad Pane Equivalent

Low-E blocks (thermal) radiation

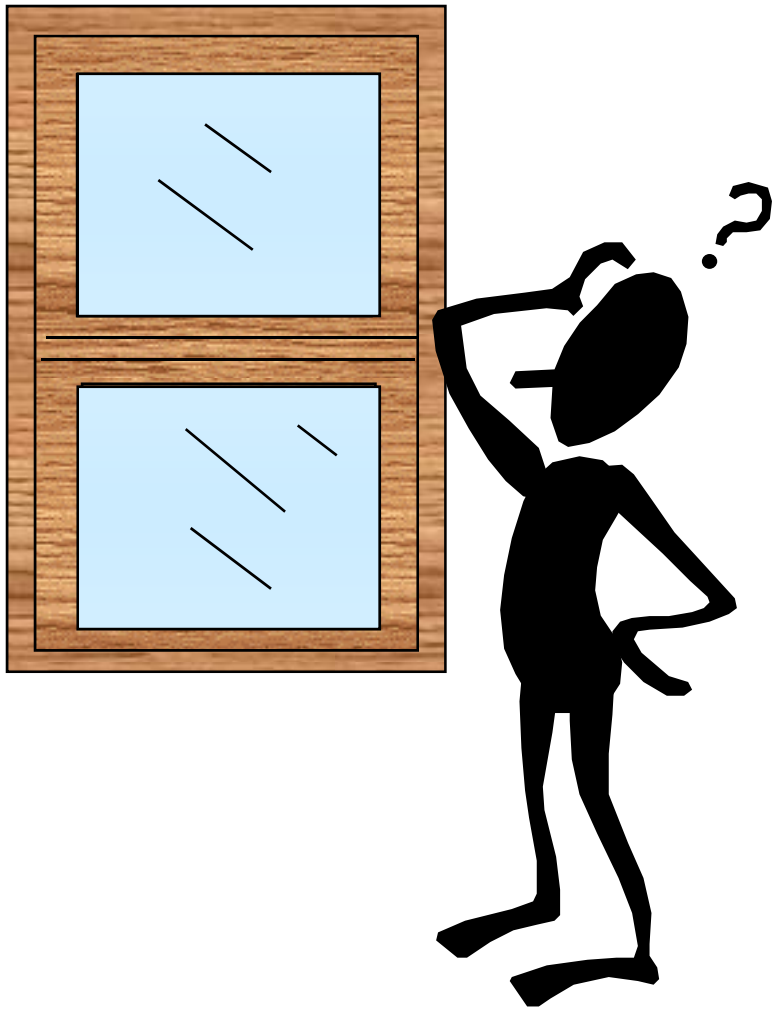
Argon slows conduction

Warm edge reduces conduction losses



The Former Problem…

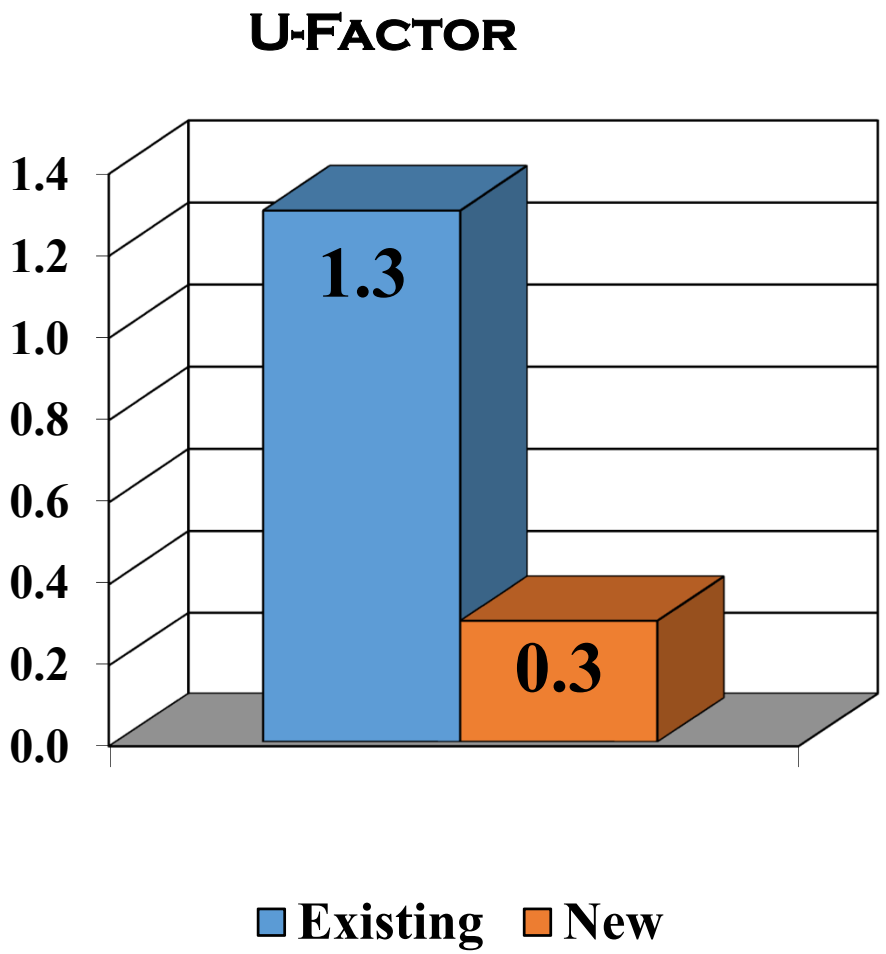
- Does it have…
  - Low-E coatings?
    - Which one?
  - Gas fills? Which one?
  - Low-conductivity spacers?
- Does it meet…
  - Local codes?
  - Performance expectations?
  - Comfort expectations?
- Known Impact on Sizing Calculations?



NFRC Label

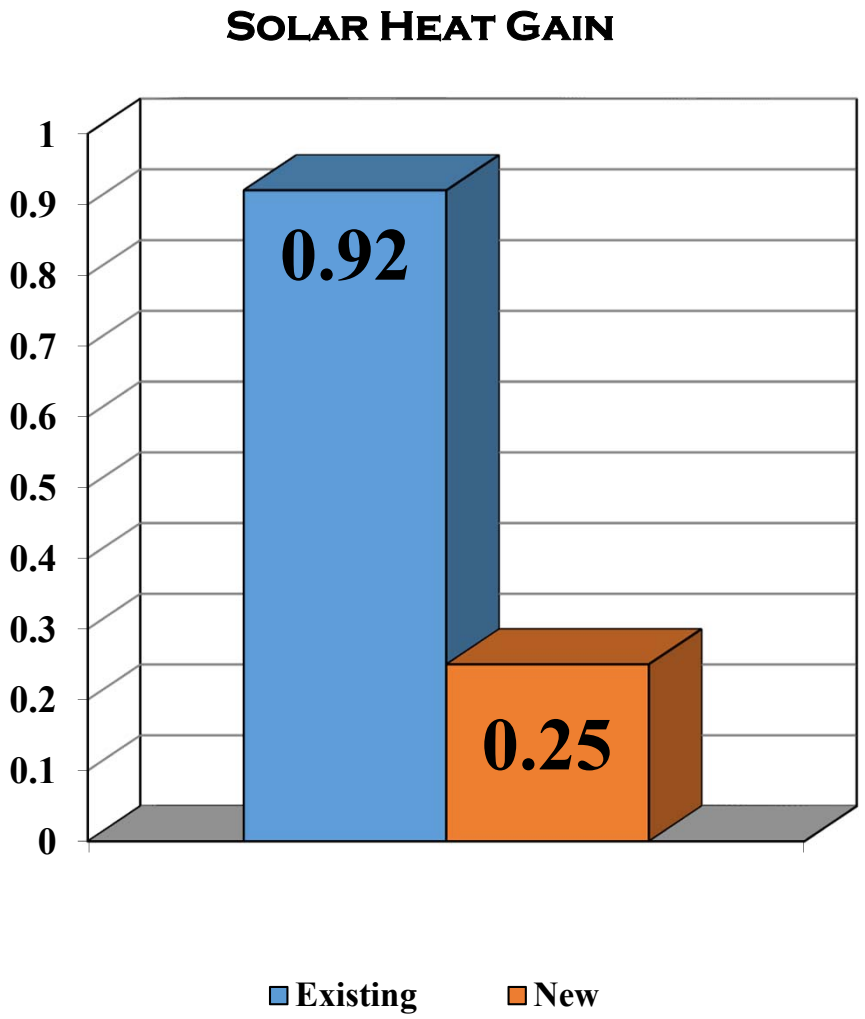
- Certified Energy Performance is Required
  - U-factor
  - SHGC

Heat Loss (winter)



- Today's code compliant windows have less than one-quarter of the heat loss in winter than common aluminum-framed, single glazed windows.
- Preventing cold glass surfaces and recurring condensation
- Big impact on winter comfort
- Heating energy savings

Heat Gain (summer)



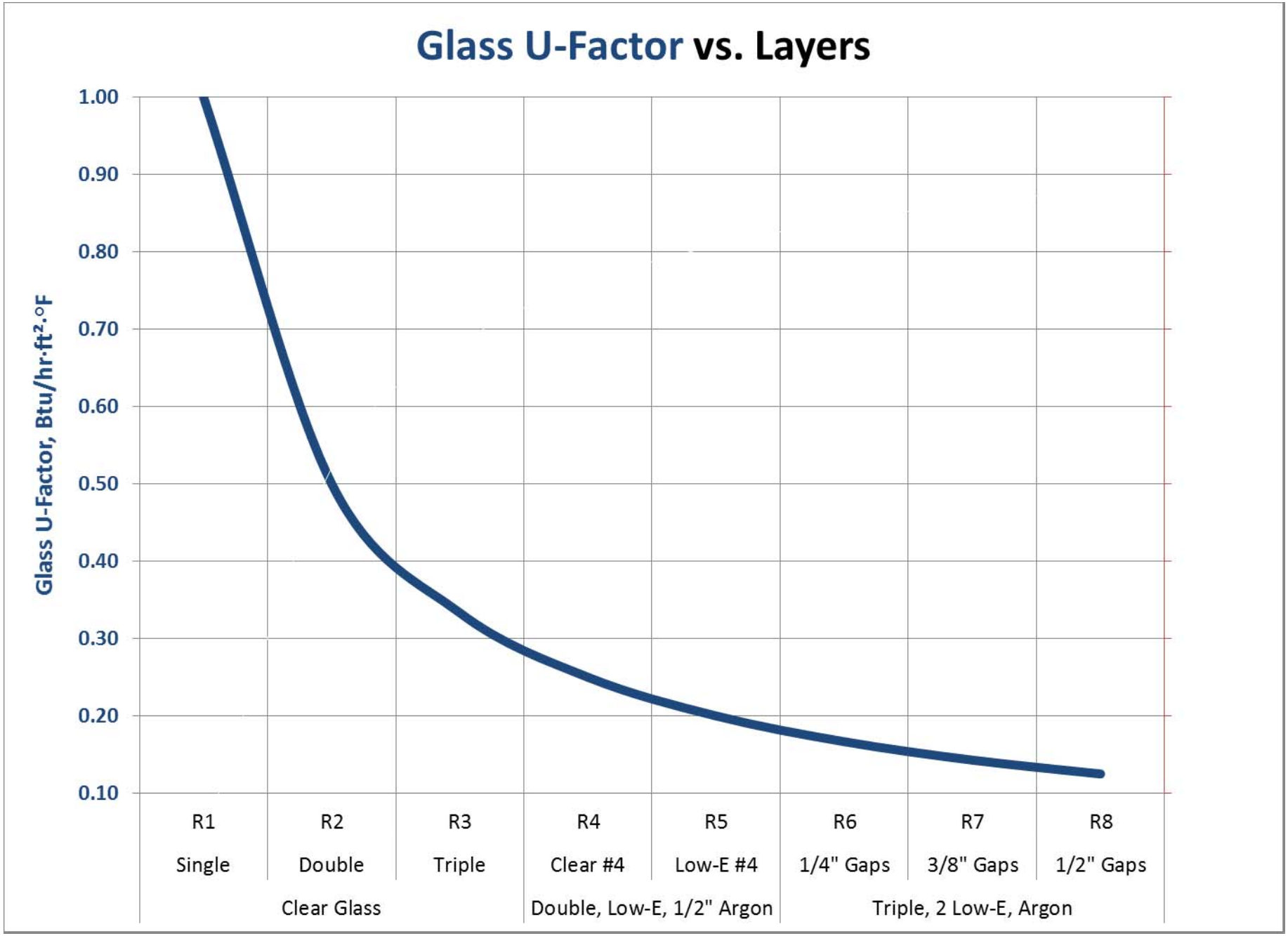
- Today's code compliant windows are over three times more effective at blocking unwanted heat gain than common aluminum-framed, single glazed windows
- Window solar gain generally drives the air conditioning load (residential)
- Window solar gain generally drives the perimeter load (commercial)

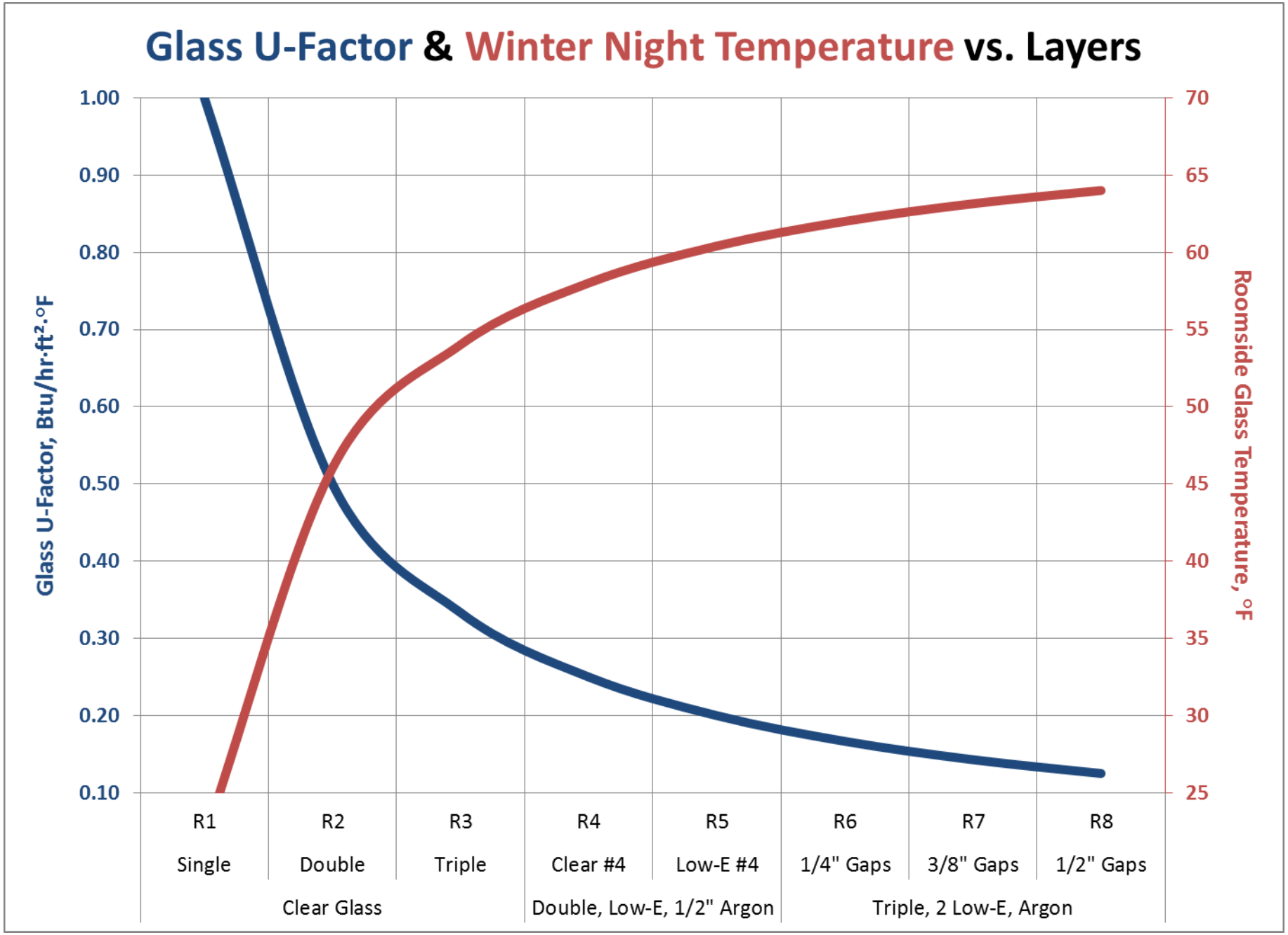
Back to the Future: More Panes?

- Single Pane ~ R1
- Double Pane ~ R2
- Triple Pane ~ R3
- Quad Pane ~ R4

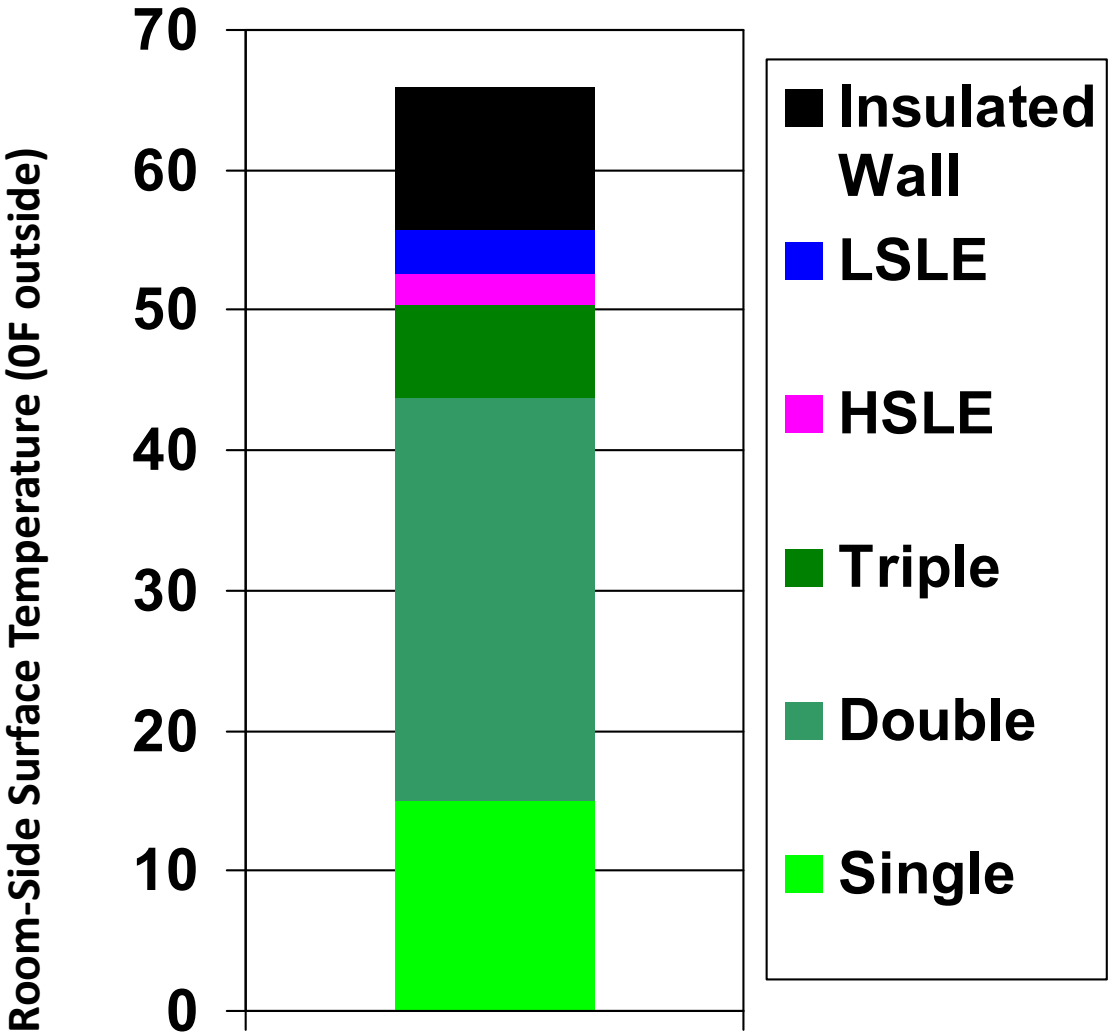
- 2 Pane + Low-E ~ R3
- 2P + Low-E + Argon ~ R4

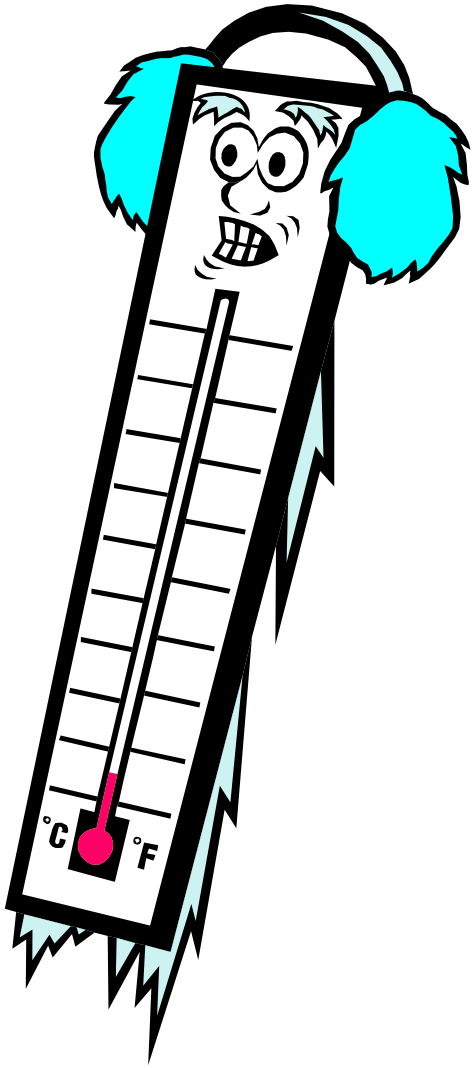
- Triple w/2 Low-E + Argon ~ R8

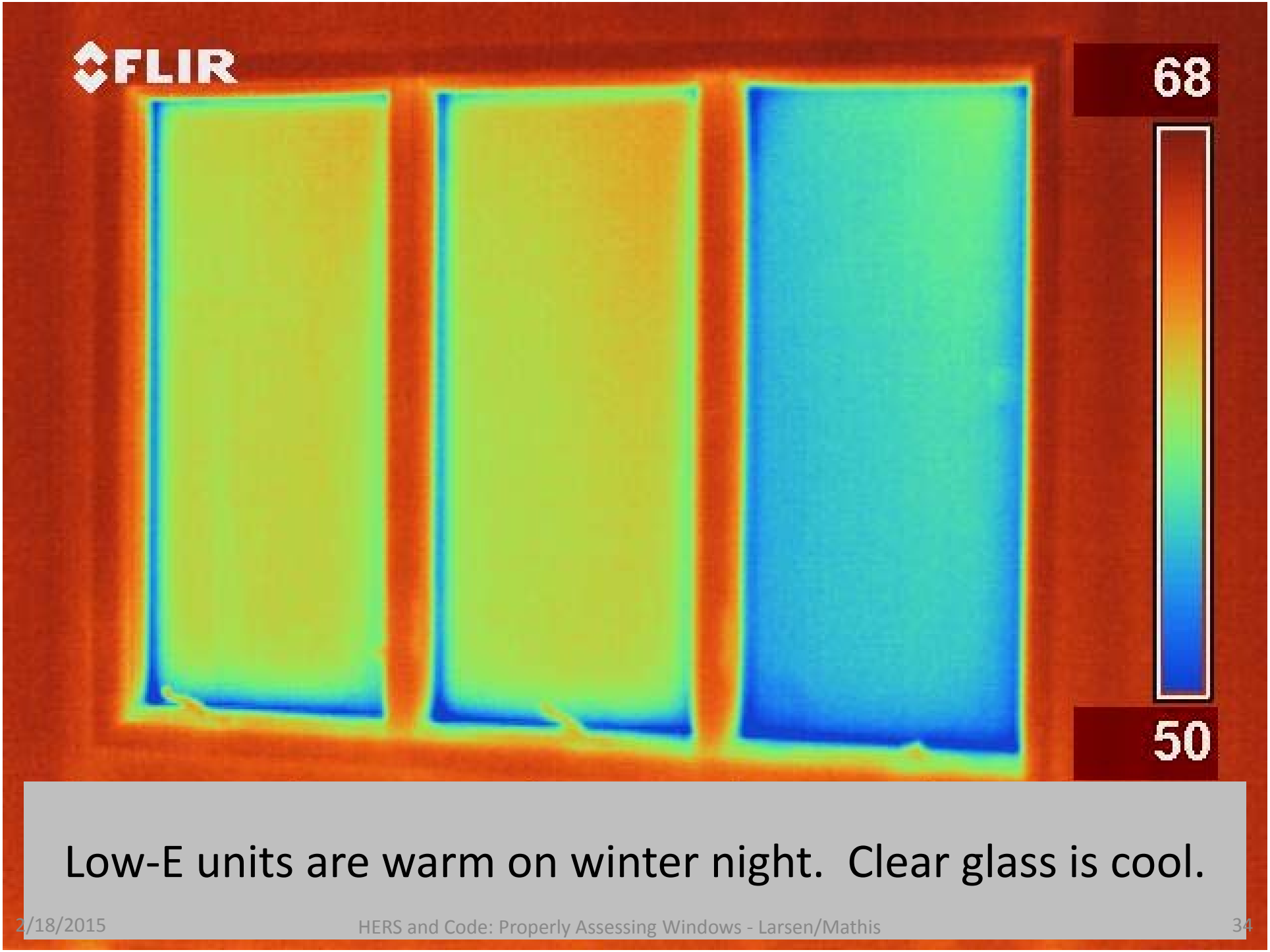

Glass U-Factor vs. Layers
Glass U-Factor, Btu/hr·ft².°F
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
R1
Single
R2
Double
R3
Triple
R4
Clear #4
R5
Low-E #4
R6
1/4" Gaps
R7
3/8" Gaps
R8
1/2" Gaps
Clear Glass
Double, Low-E, 1/2" Argon
Triple, 2 Low-E, Argon


Glass U-Factor & Winter Night Temperature vs. Layers
Glass U-Factor, Btu/hr·ft².°F
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
Roomside Glass Temperature, °F
70
65
60
55
50
45
40
35
30
25
R1
Single
R2
Double
R3
Triple
R4
Clear #4
R5
Low-E #4
R6
1/4" Gaps
R7
3/8" Gaps
R8
1/2" Gaps
Clear Glass
Double, Low-E, 1/2" Argon
Triple, 2 Low-E, Argon

Winter Comfort

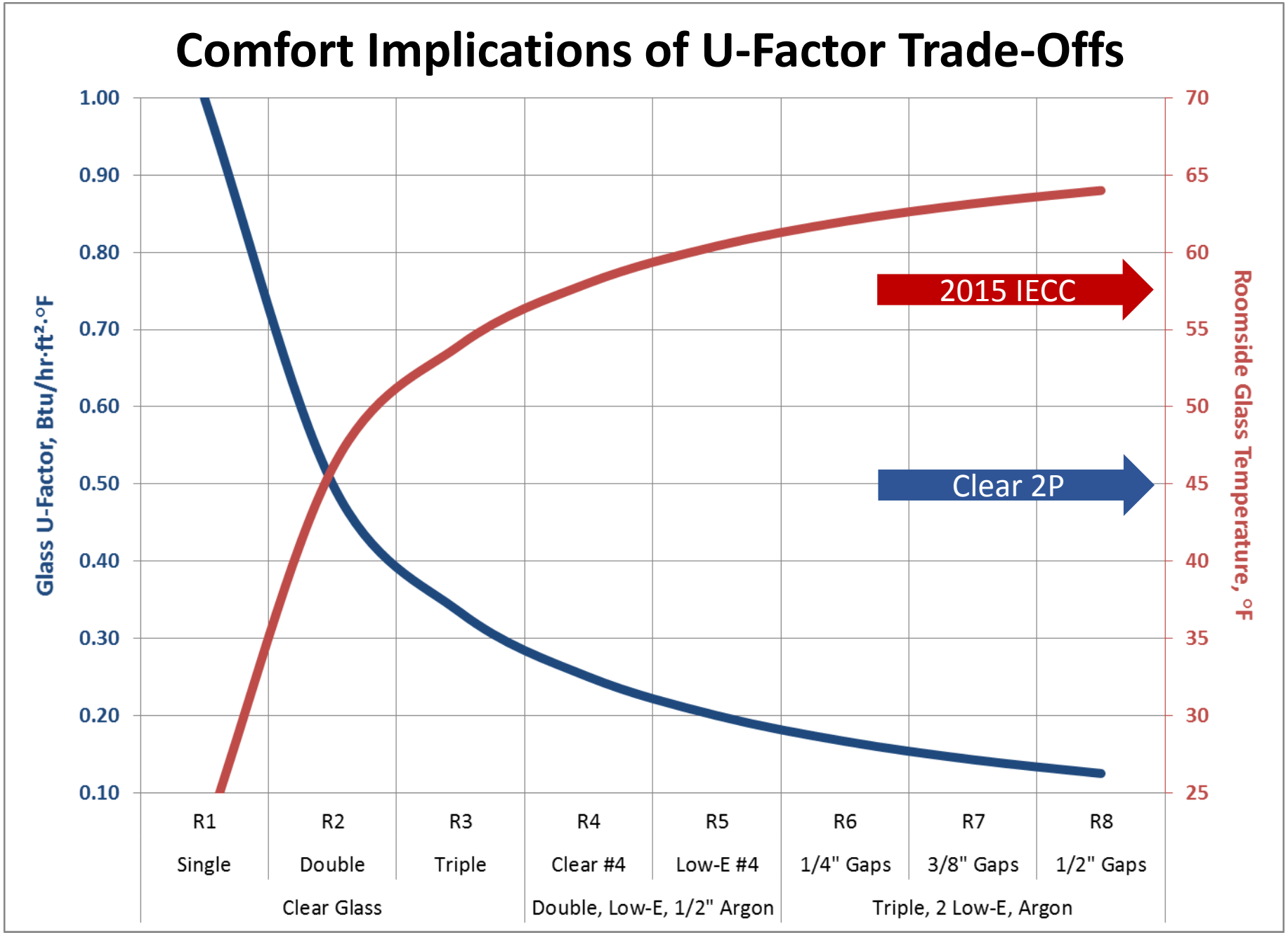






Low-E units are warm on winter night. Clear glass is cool.

Comfort Implications of U-Factor Trade-Offs



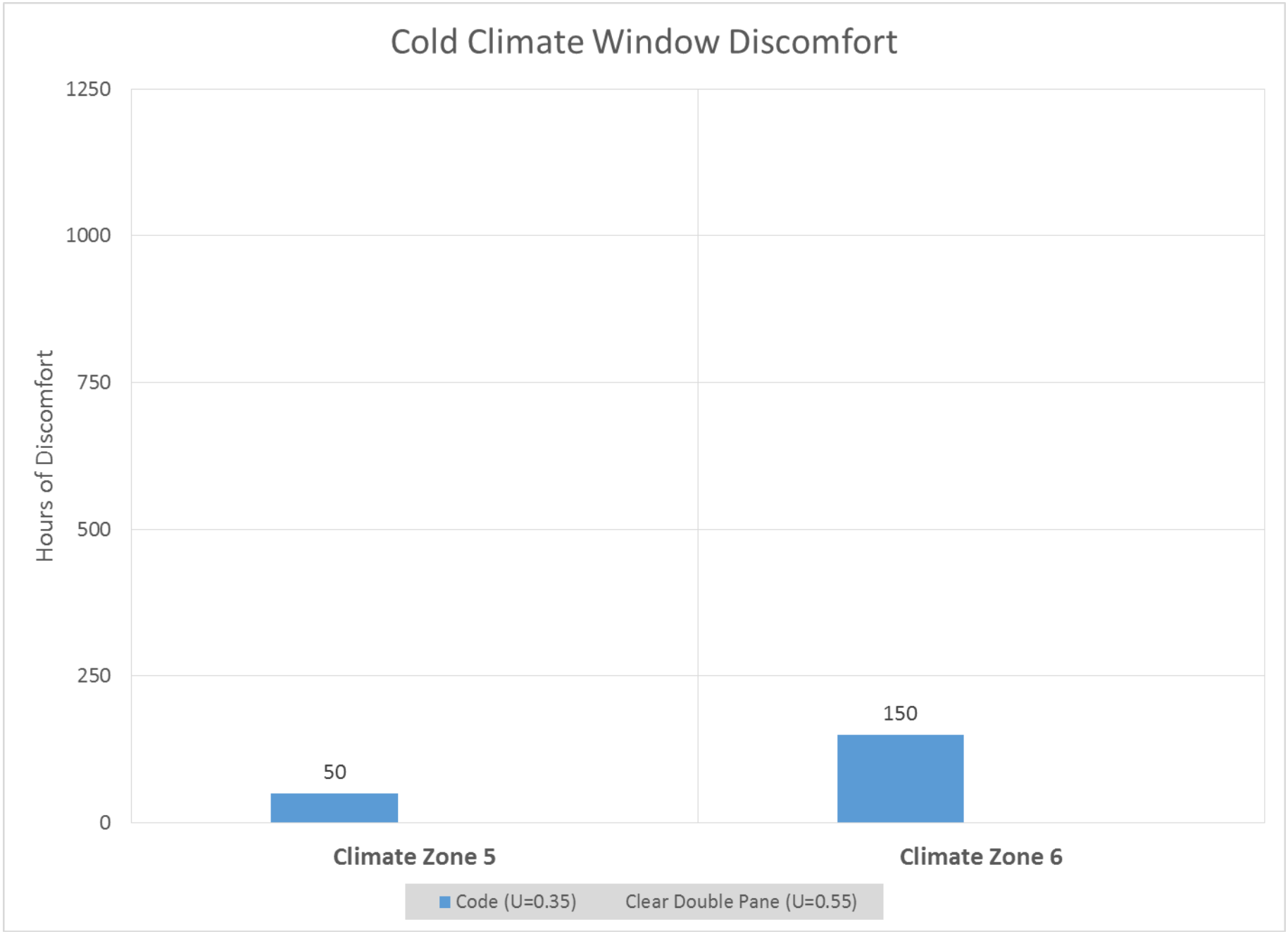
Comfort Comparison

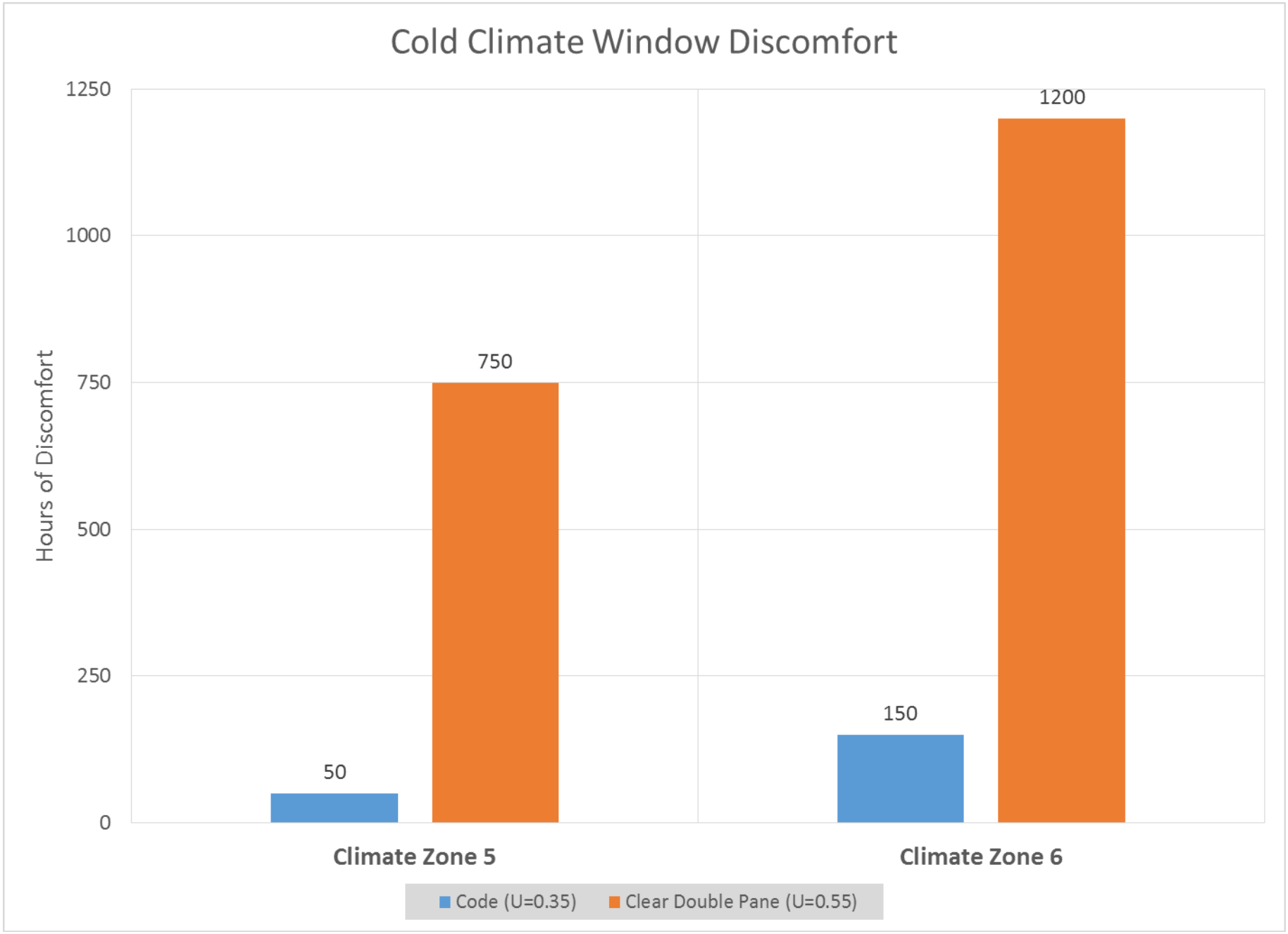
- The roomside glass surface temperature of a code window (U=0.35) at 0°F ambient rating condition is 56°F.

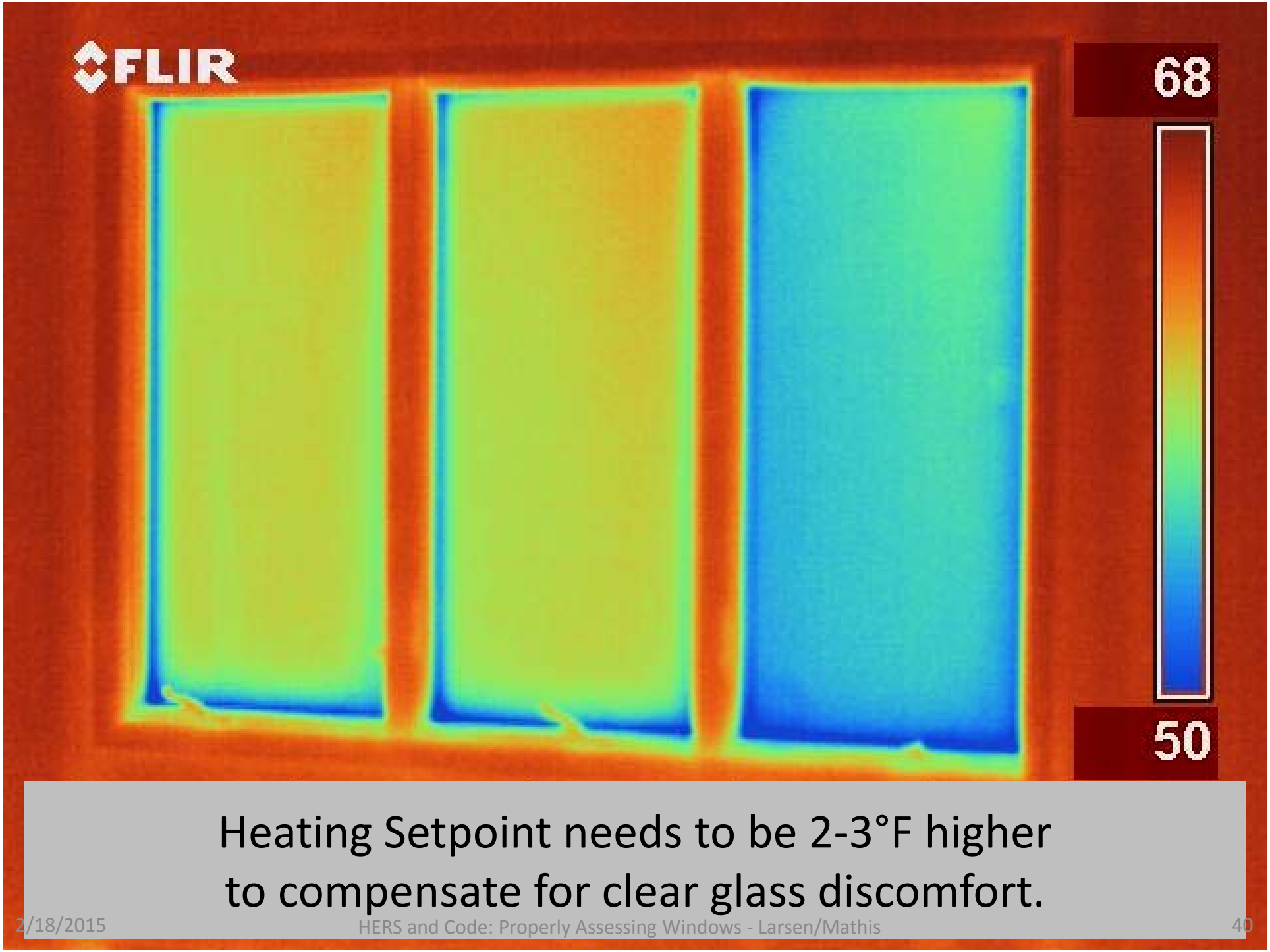
Presume Code is Comfortable

- Calculate the number of hours in a season that roomside temperature is below 56°F threshold.

- Next two plots compare hours of discomfort for a code window (U=0.35) in climate zones 5 & 6 and the comfort implications of trading back to clear double pane glass (U=0.55)


Cold Climate Window Discomfort
1250
1000
750
500
250
0
Hours of Discomfort
50
150
Climate Zone 5
Climate Zone 6
Code (U=0.35)
Clear Double Pane (U=0.55)


Cold Climate Window Discomfort
Hours of Discomfort
1250
1000
750
500
250
0
50
750
150
1200
Climate Zone 5
Climate Zone 6
Code (U=0.35)
Clear Double Pane (U=0.55)



Heating Setpoint needs to be 2-3°F higher to compensate for clear glass discomfort.

Traditional Options for Solar Control

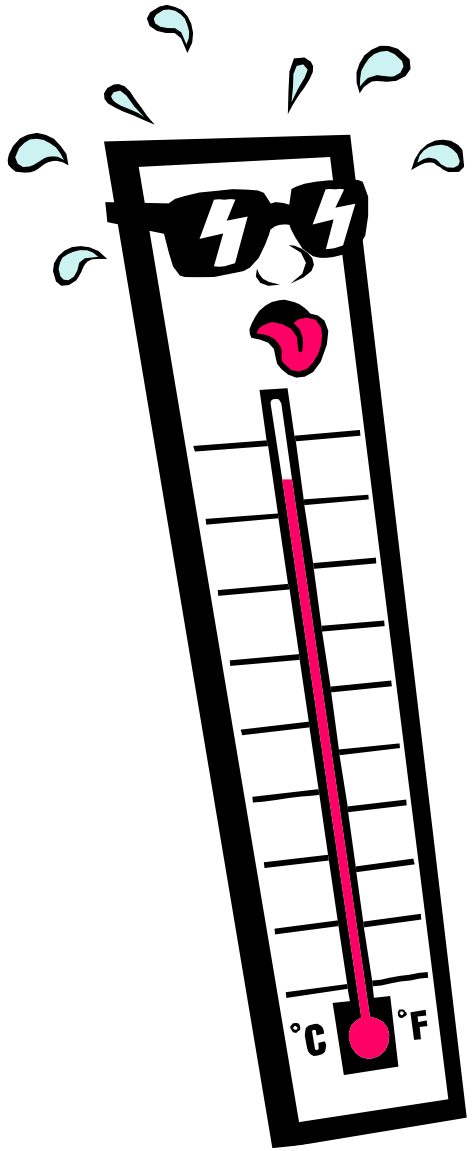
Tinted Glass

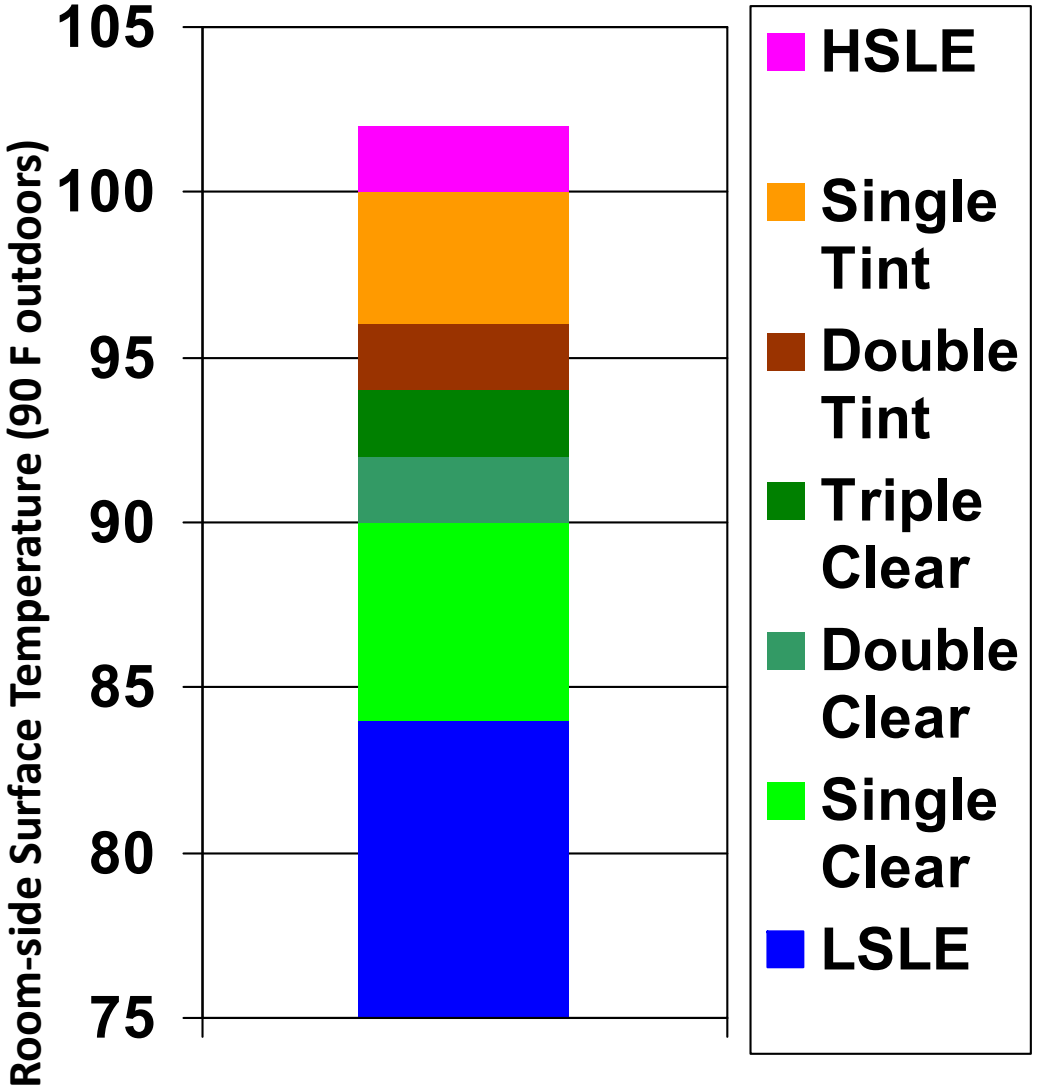
- **Adds color to "body" of glass**
- **Absorbs sunlight and re-radiates to exterior**

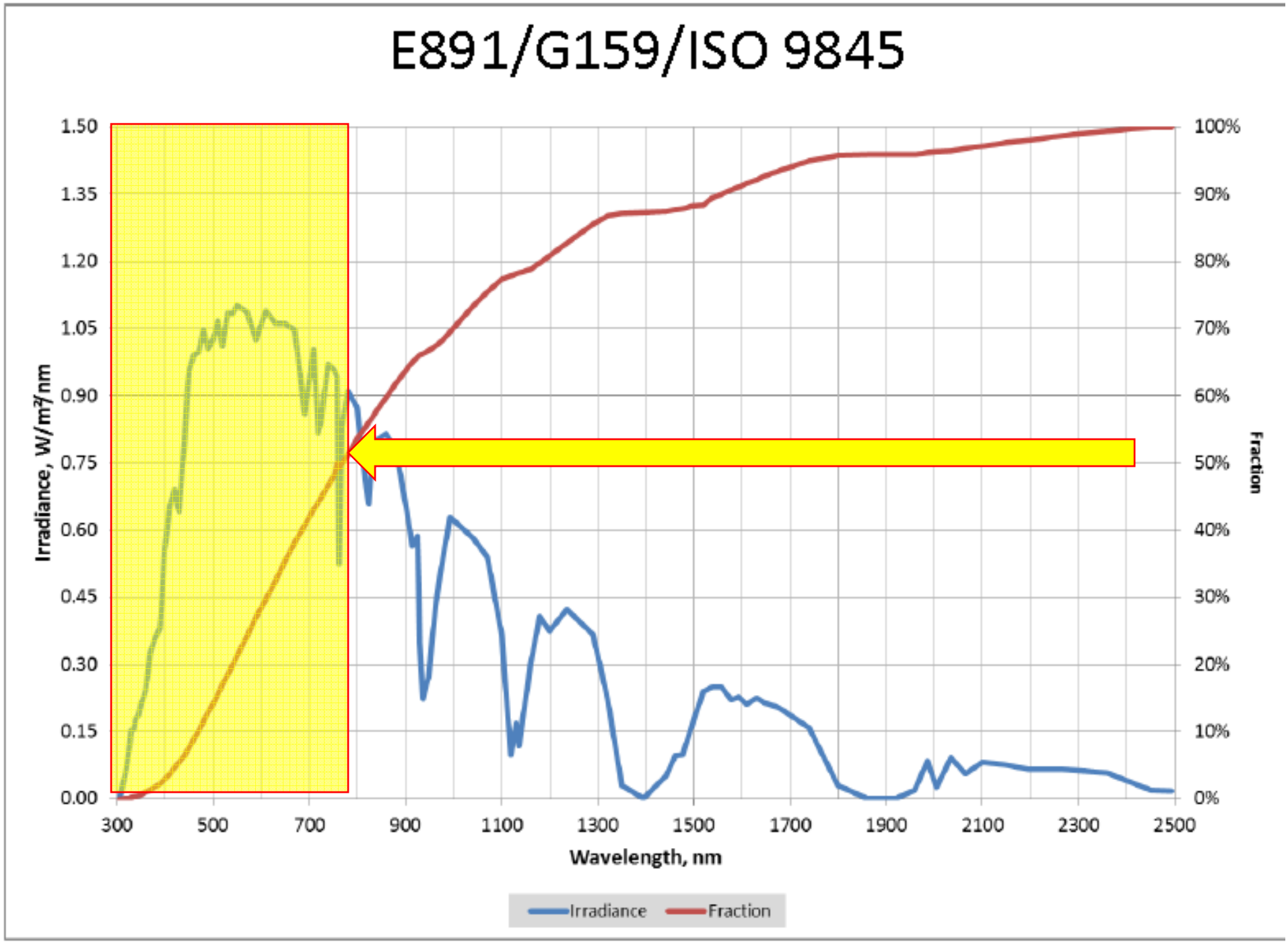
Reflective Glass

- **Mirror appearance**
- **Reflects sunlight out**

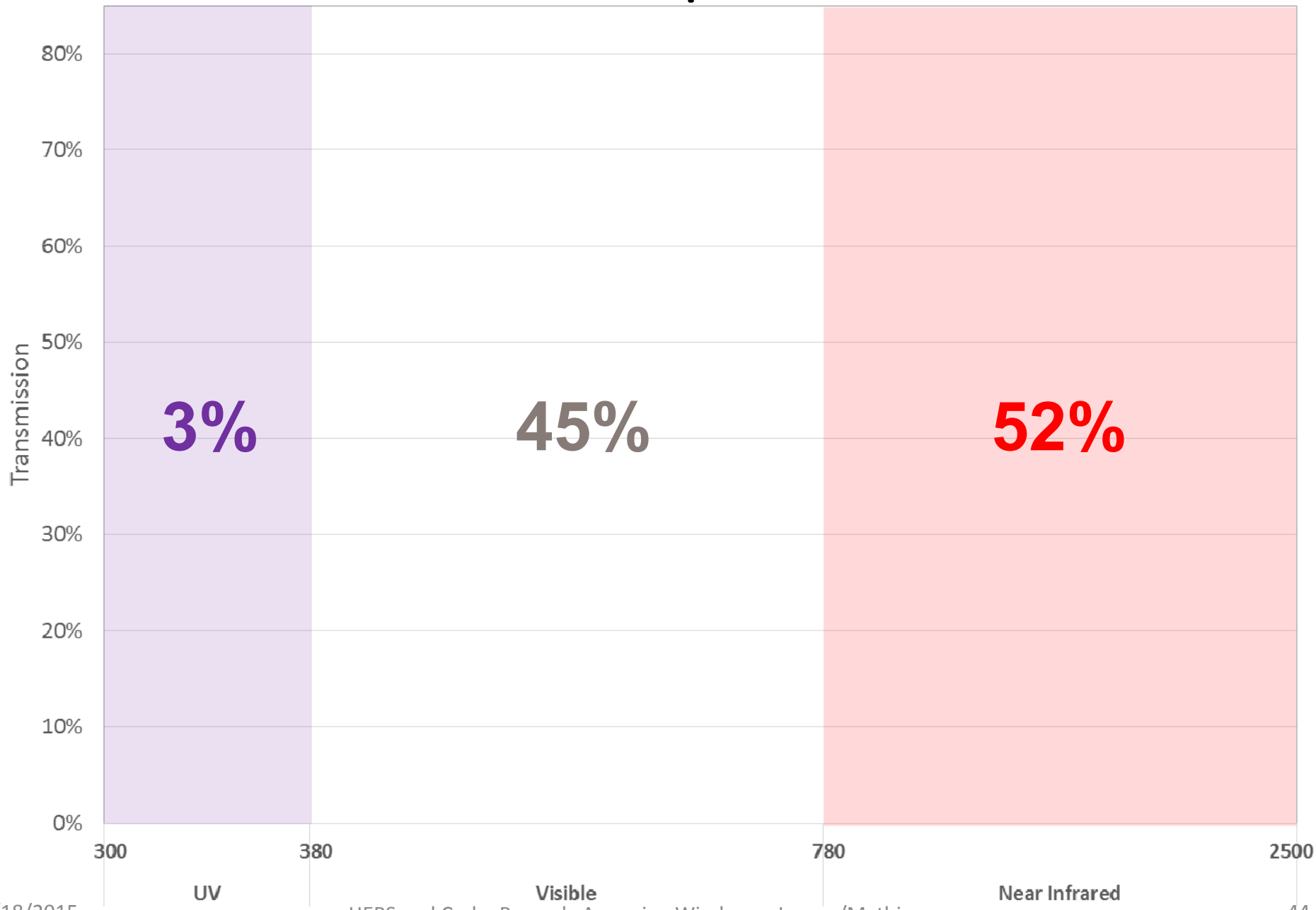
Summer Comfort



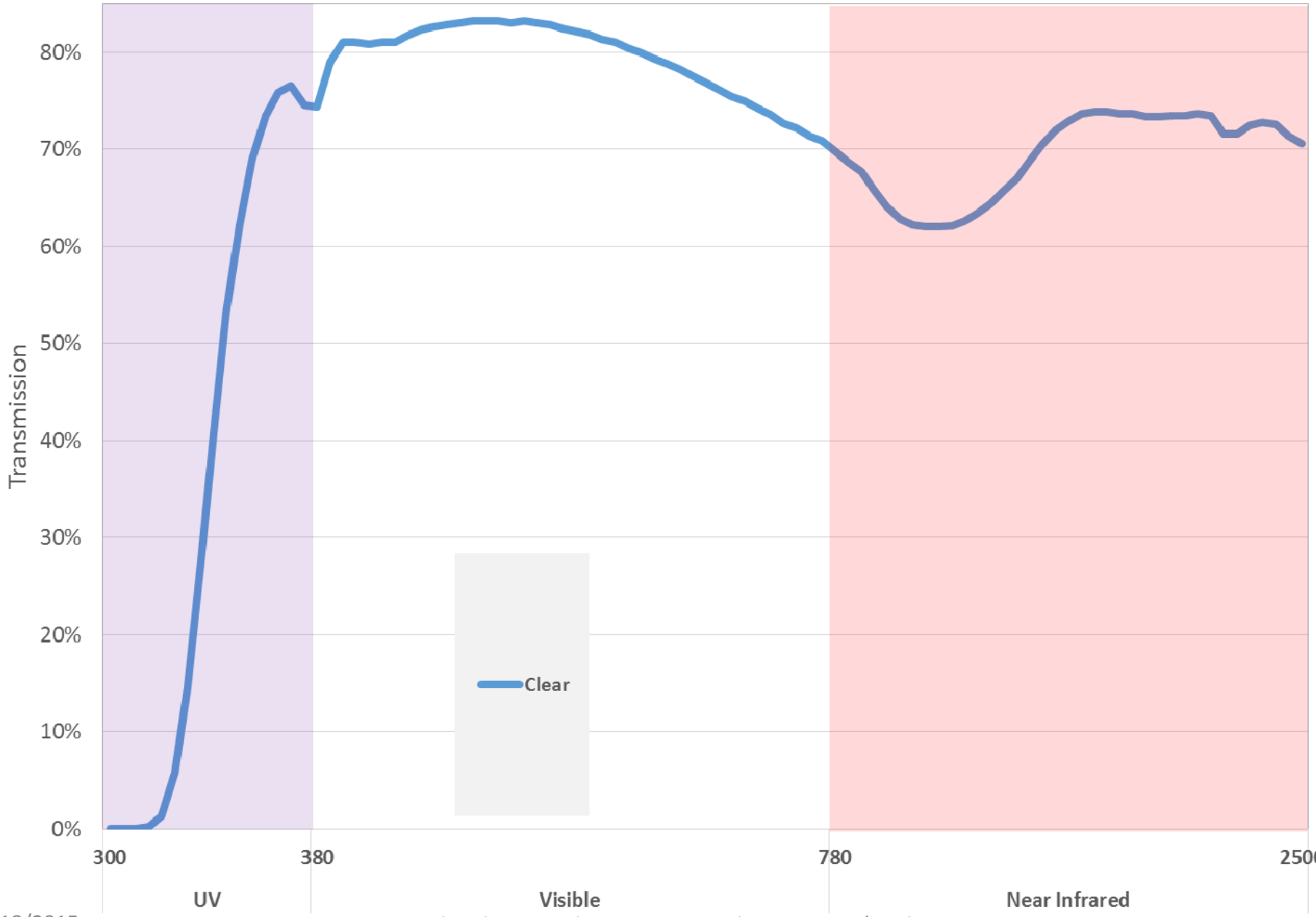



E891/G159/ISO 9845
Irradiance, W/m²/nm
1.50
1.35
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Fraction
300
500
700
900
1100
1300
1500
1700
1900
2100
2300
2500
Wavelength, nm
Irradiance
Fraction

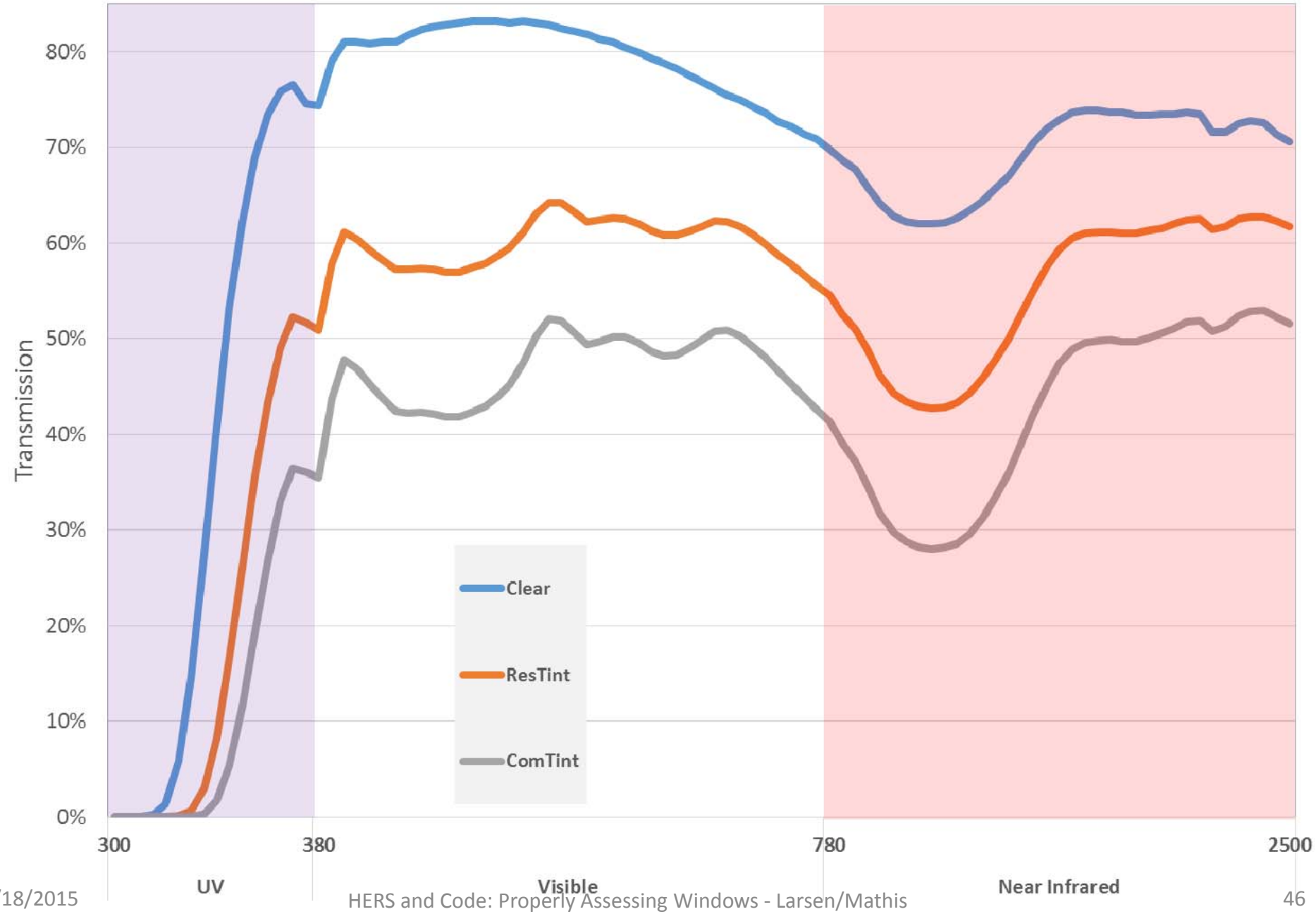
The Solar Spectrum



Clear Double Pane Glass SHGC ~ 0.75



Tinted Double Pane Glass SHGC 0.65 – 0.55



A New Option for Solar Control

Tinted Glass

- **Adds color to "body" of glass**
- **Absorbs sunlight and re-radiates to exterior**

Reflective Glass

- **Mirror appearance**
- **Reflects sunlight out**

Spectrally Selective (~1990)

- **Clear glass appearance with solar control**
- **Reflects solar infrared (invisible to human eye)**

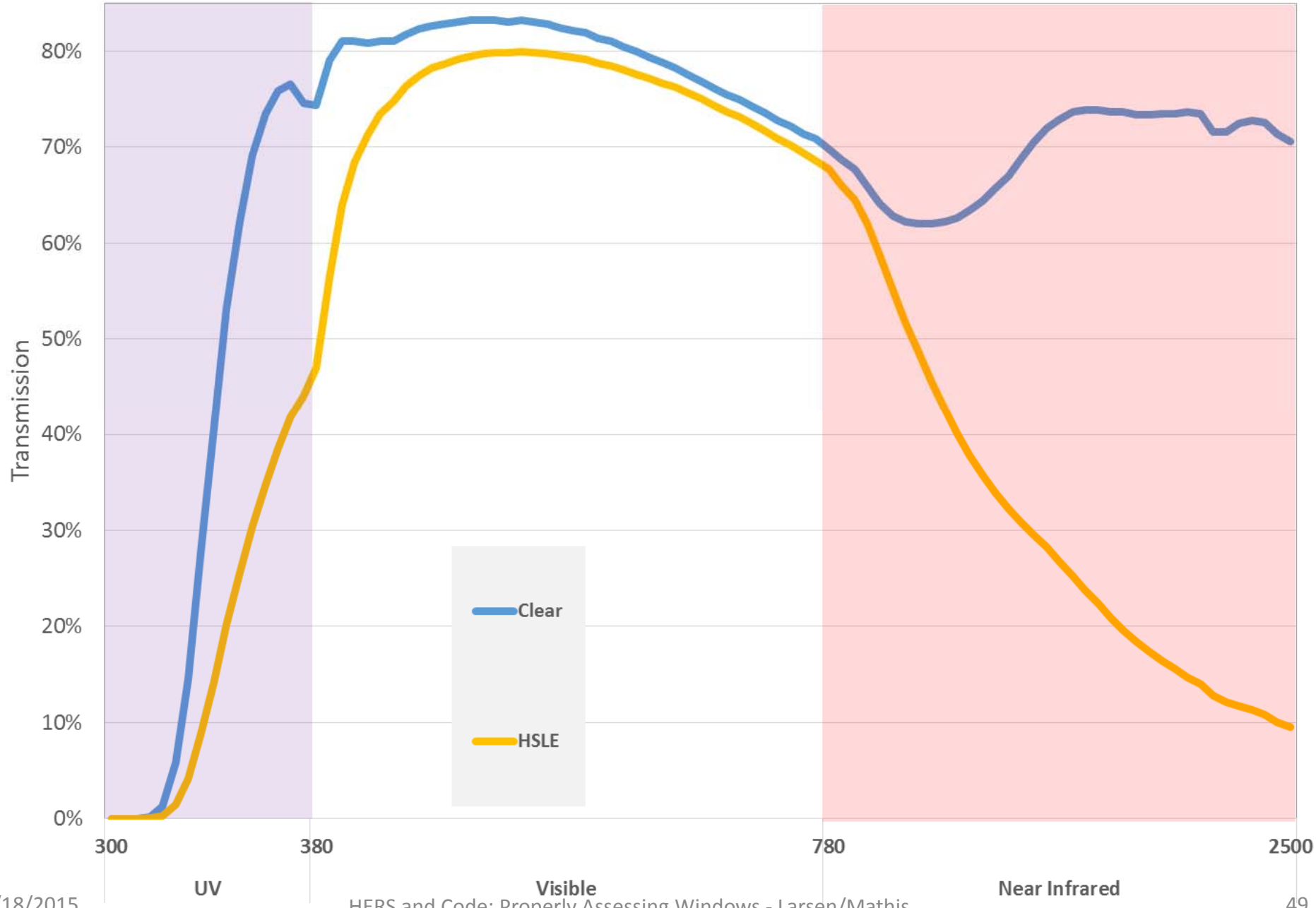
“Clear” Low-E Solar Options

High Solar Gain (HSLE)

- VT ~ 80%
- Glass SHGC ~ 0.65

- This was the 1st generation low-E introduced in the early 1980s. (heating energy savings focus)
- Even though it was promoted as a “northern” glazing and backed up by energy simulations that credit passive solar gain, the consumer response was extremely negative due to year-round overheat.

High Solar Gain Low-E: Glass SHGC ~ 0.65



“Clear” Low-E Solar Options

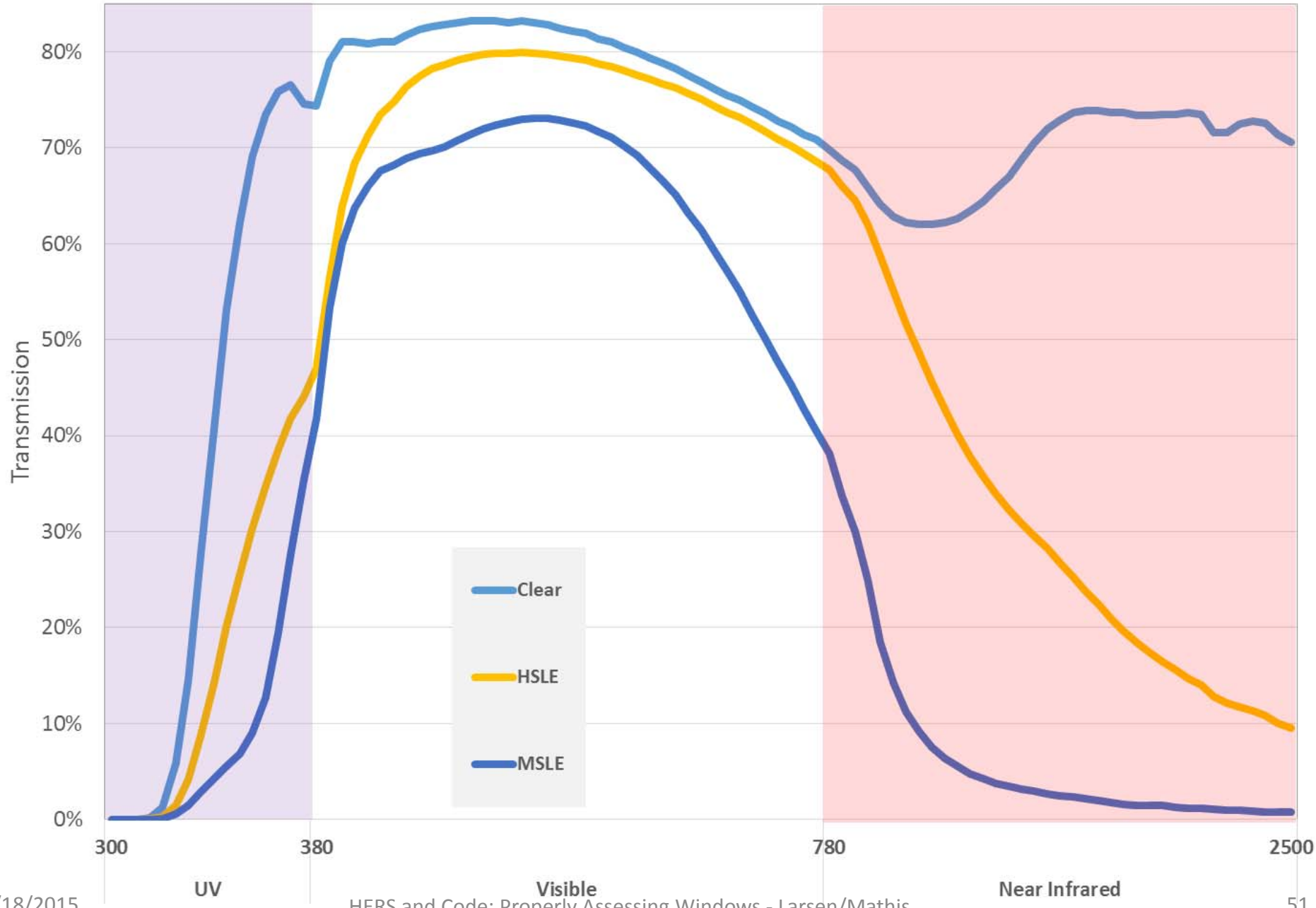
High Solar Gain (HSLE)

- VT ~ 80%
- Glass SHGC ~ 0.65

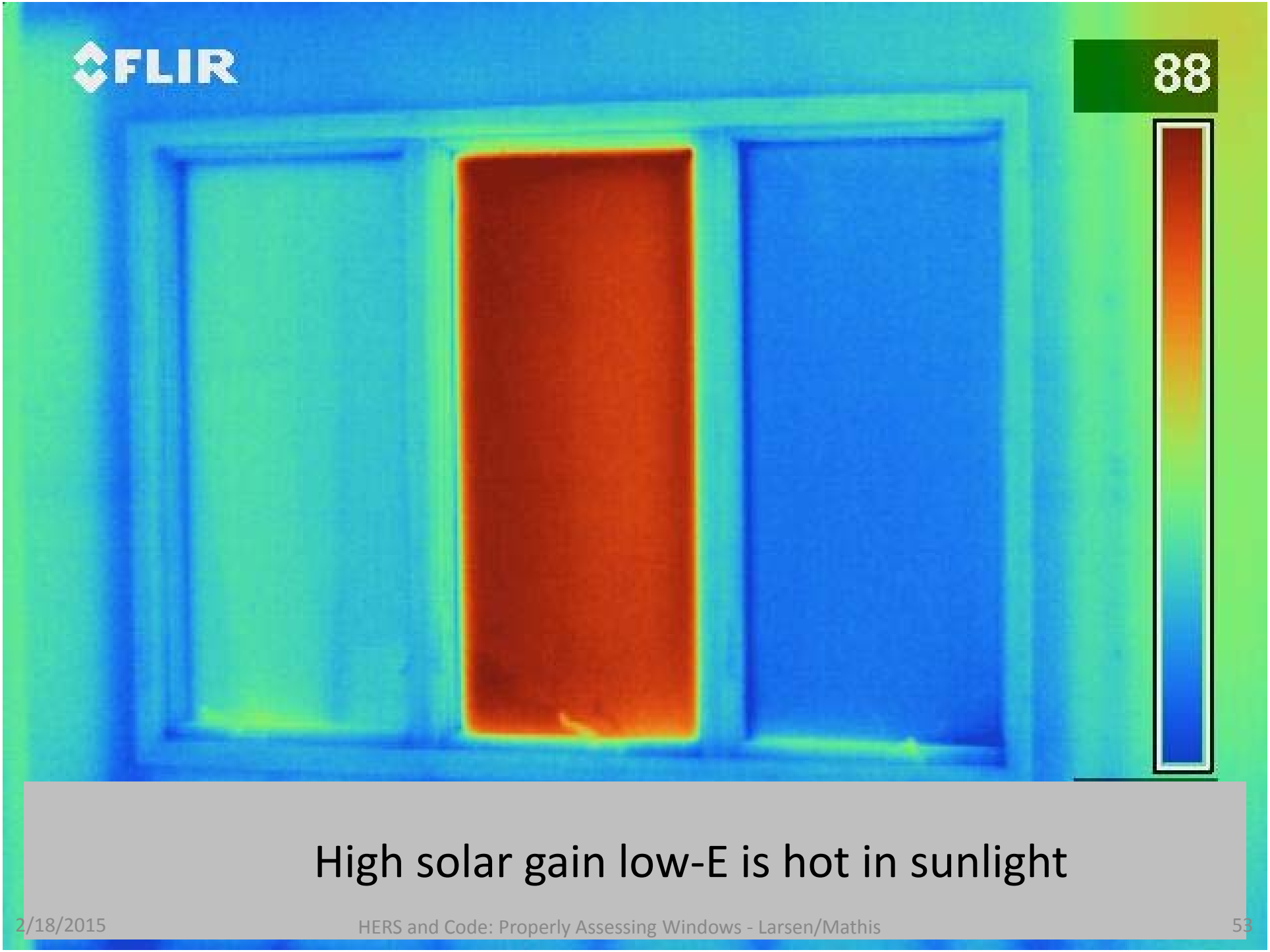
Medium Solar Gain (MSLE)

- VT ~ 70%
- Glass SHGC ~ 0.40

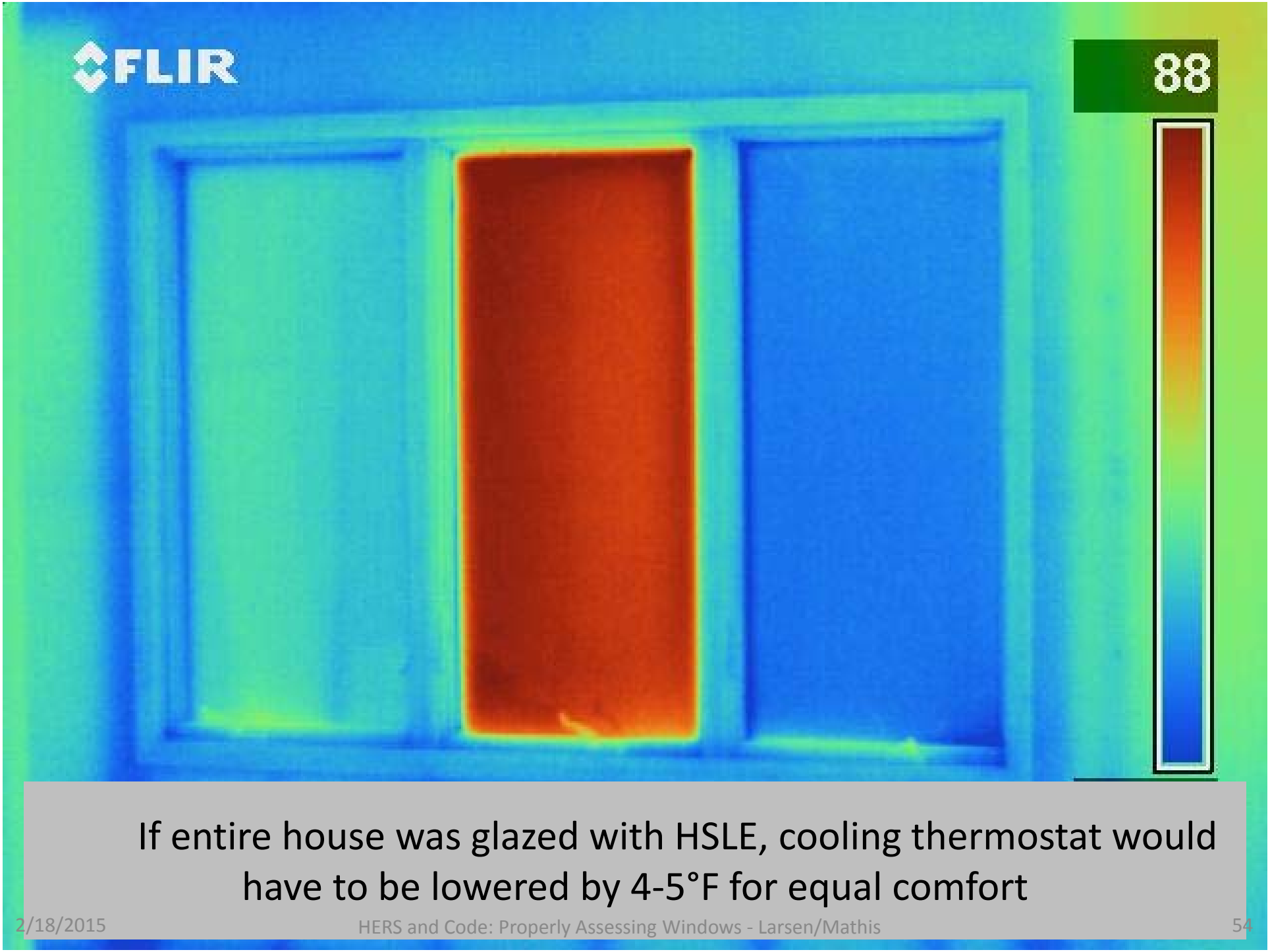
Medium Solar Gain Low-E: Glass SHGC ~ 0.40




| Low-E | Clear Glass
Med Solar | High Solar



High solar gain low-E is hot in sunlight



If entire house was glazed with HSLE, cooling thermostat would have to be lowered by 4-5°F for equal comfort

“Clear” Low-E Solar Options

High Solar Gain (HSLE)

- VT ~ 80%
- Glass SHGC ~ 0.65

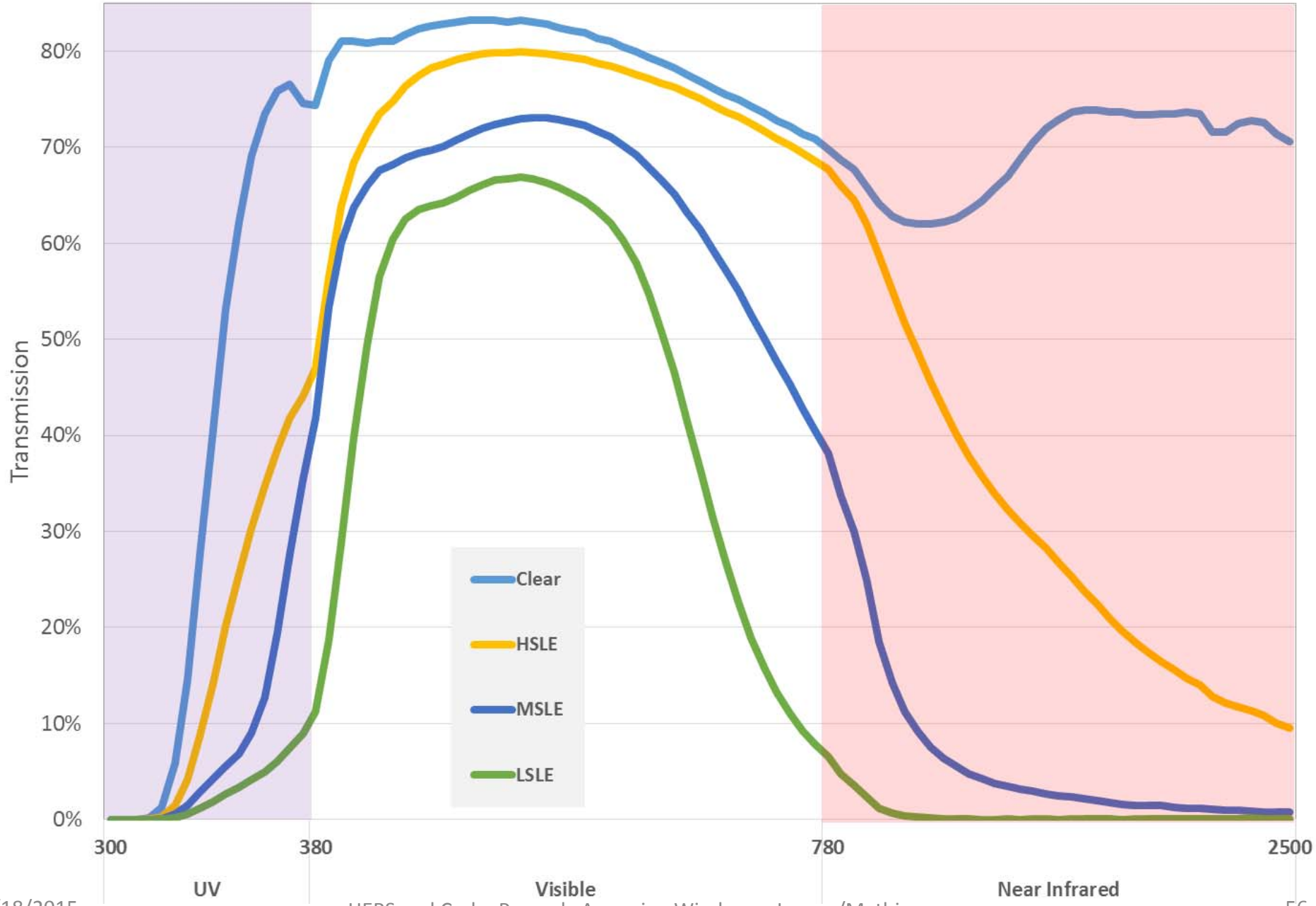
Medium Solar Gain (MSLE)

- VT ~ 70%
- Glass SHGC ~ 0.40

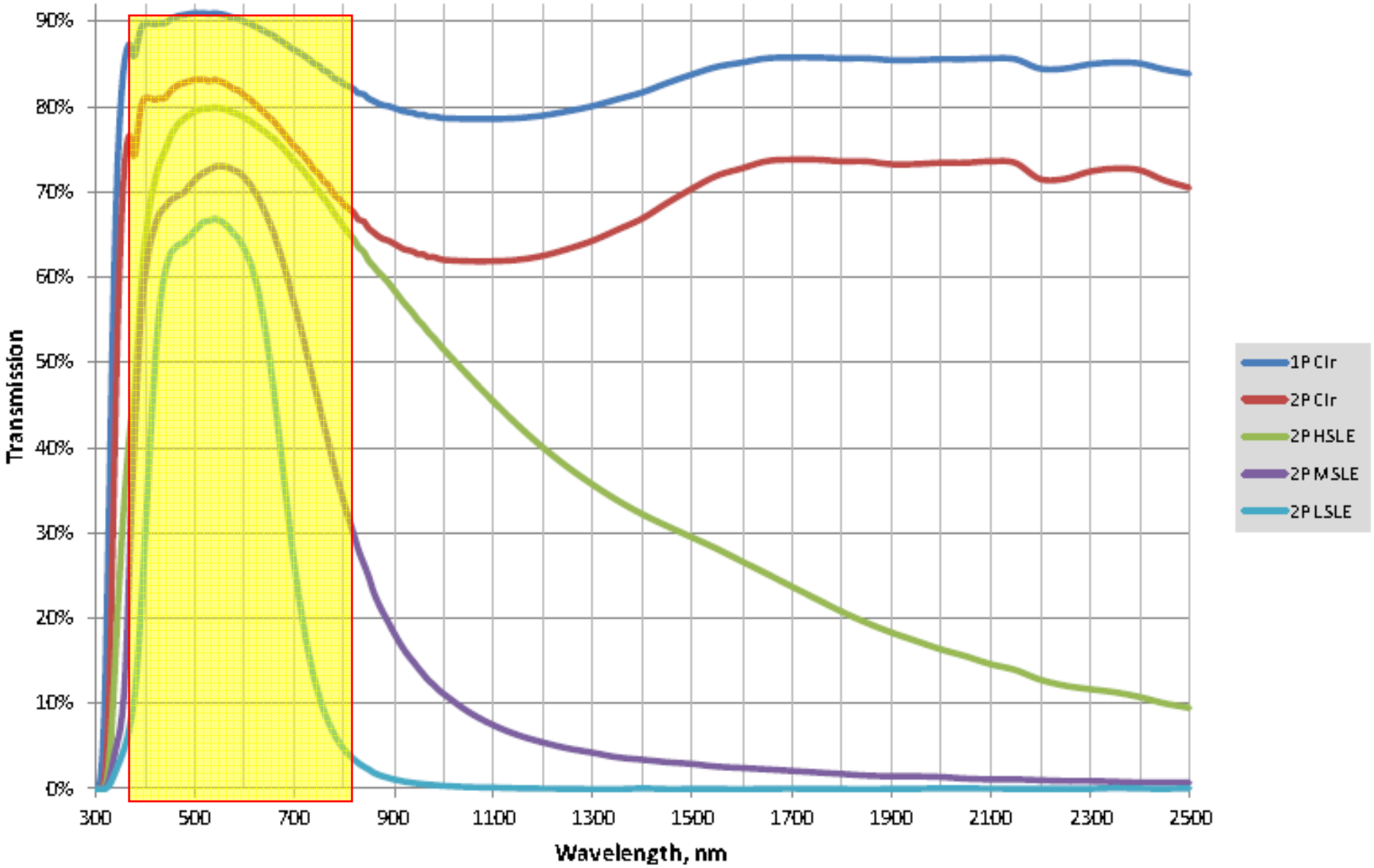
Low Solar Gain (LSLE)

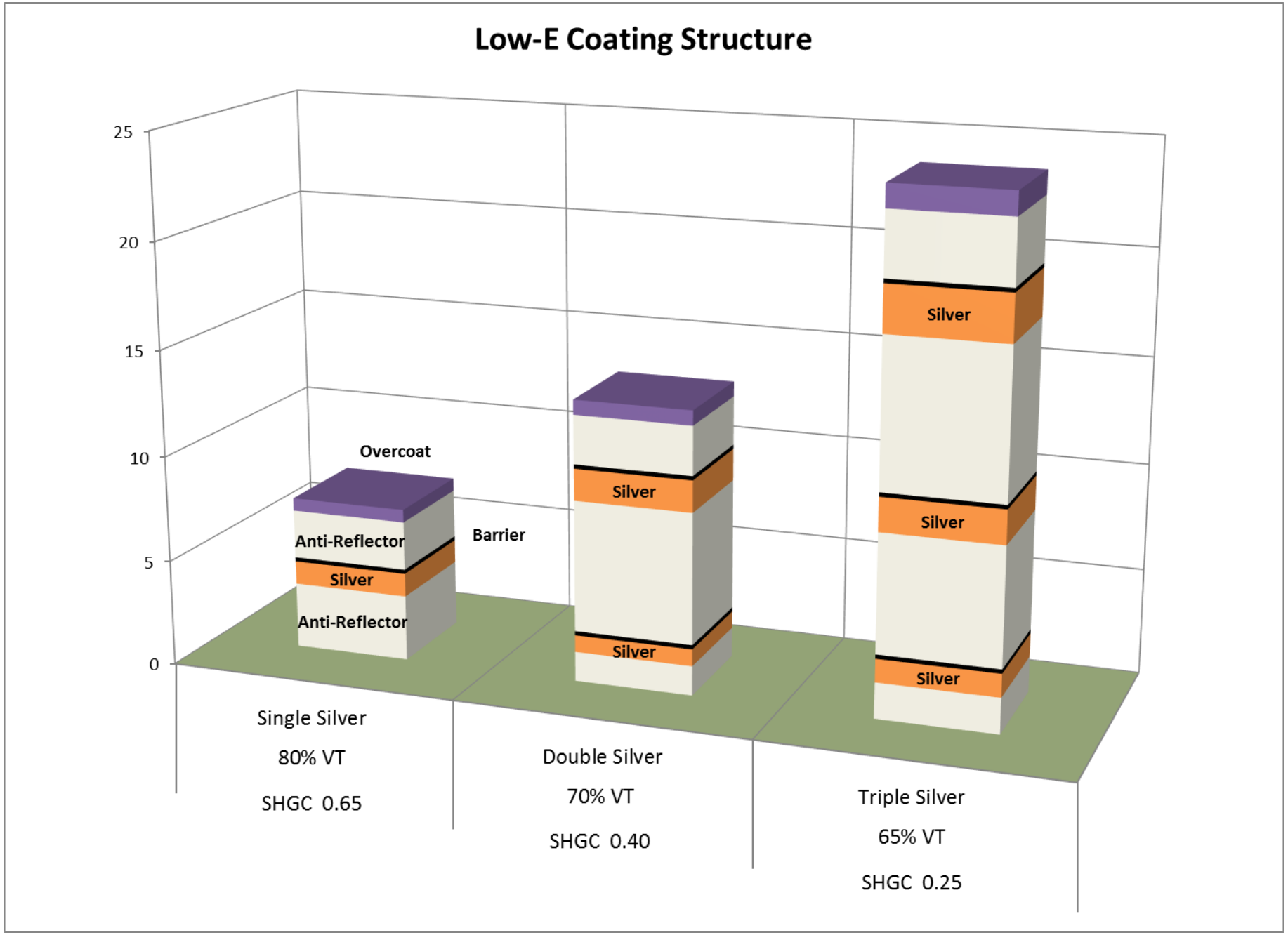
- VT ~ 65%
- Glass ~ 0.25

Low Solar Gain Low-E: Glass SHGC ~ 0.25



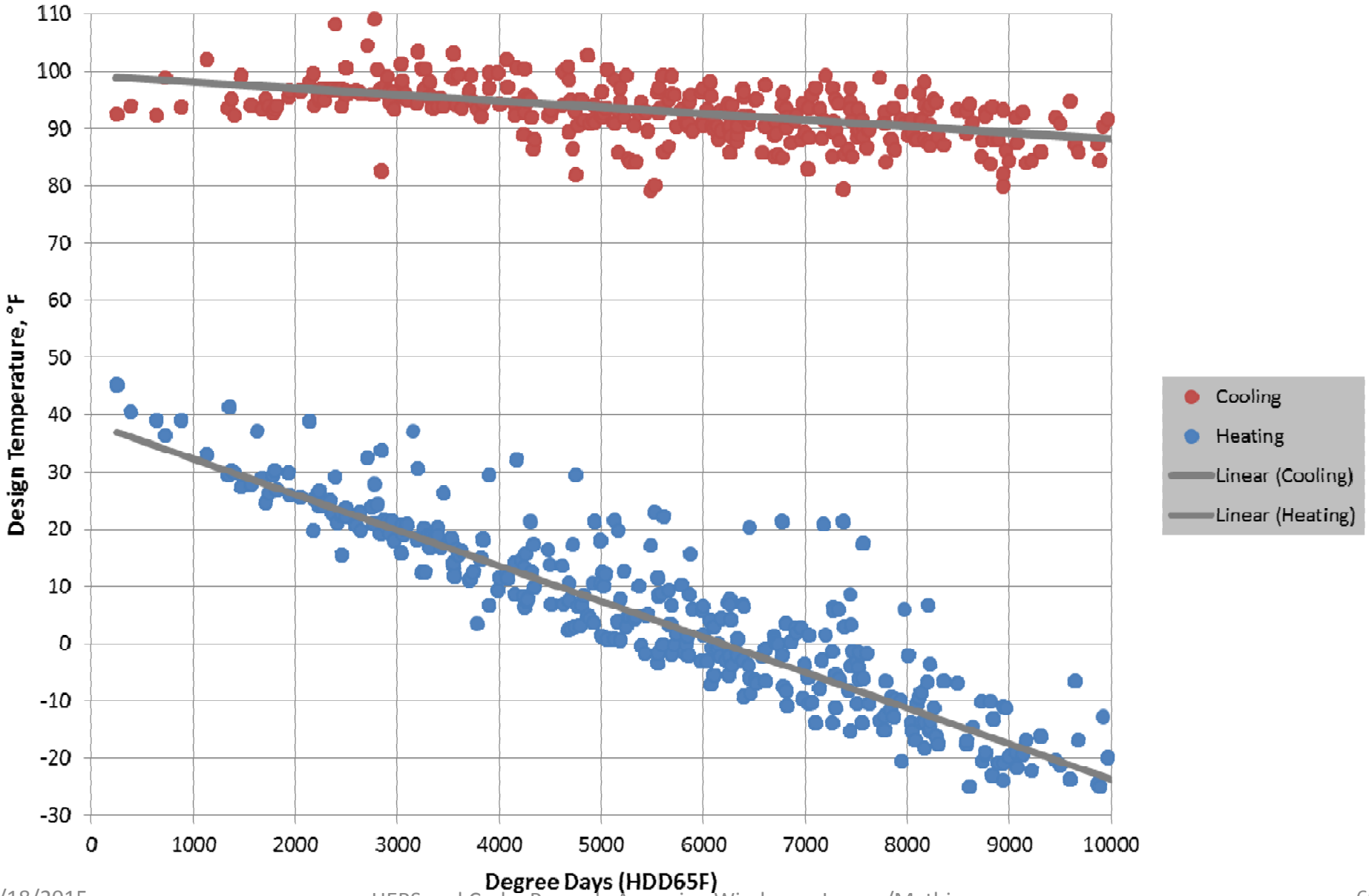
Full Spectrum Width



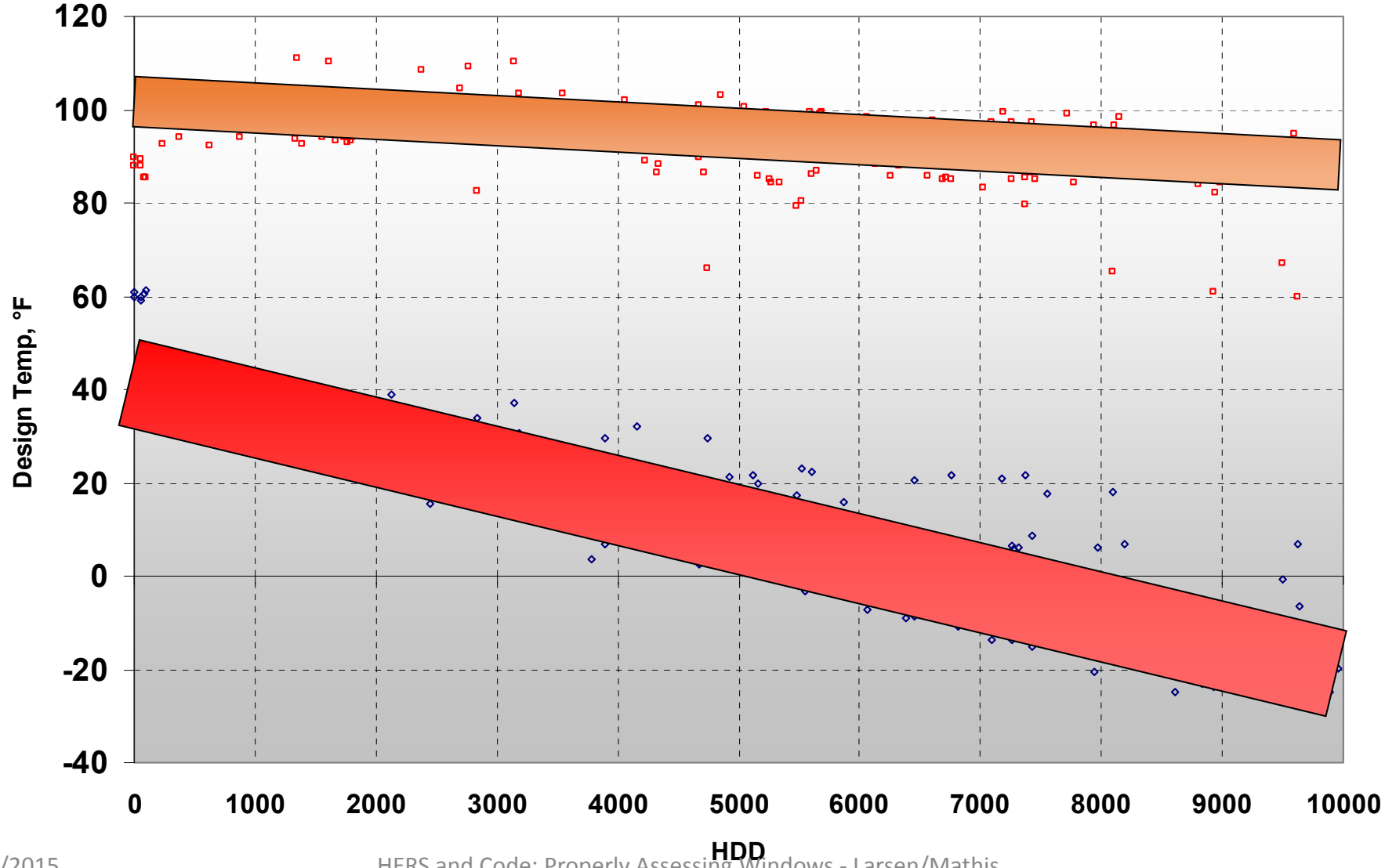

Low-E Coating Structure
25
20
15
10
5
0
Overcoat
Anti-Reflector
Silver
Anti-Reflector
Barrier
Silver
Silver
Silver
Silver
Silver
Single Silver
80% VT
SHGC 0.65
Double Silver
70% VT
SHGC 0.40
Triple Silver
65% VT
SHGC 0.25

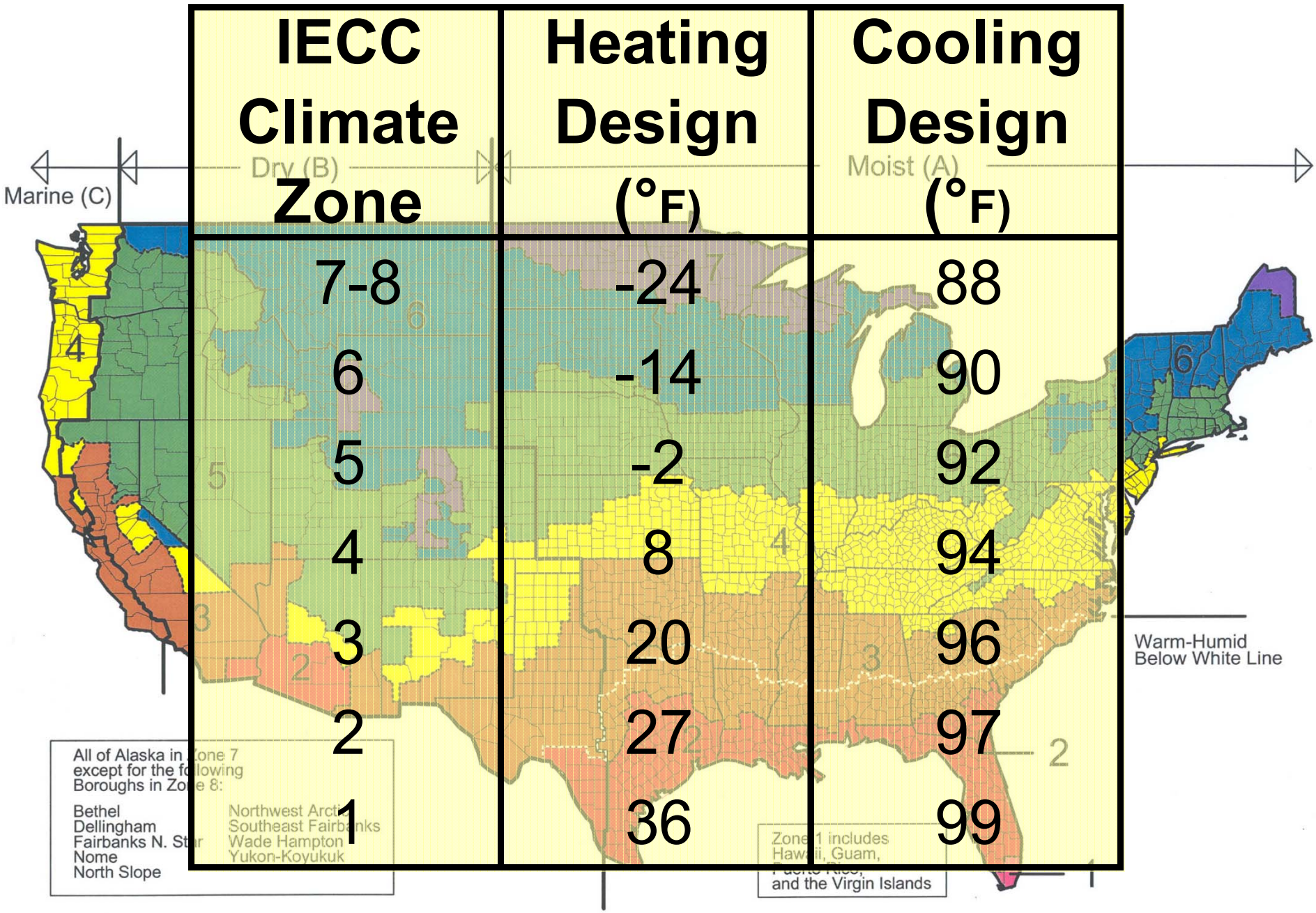
Windows and Comfort

Reminder: Design Temperatures



Heating and Cooling Design Ts





IECC Climate Zone	Heating Design (°F)	Cooling Design (°F)
7-8	-24	88
6	-14	90
5	-2	92
4	8	94
3	20	96
2	27	97
1	36	99

Code and Window Comfort

- The prescriptive window requirements in the 2015 IECC provide a reasonable surrogate for minimally acceptable comfort

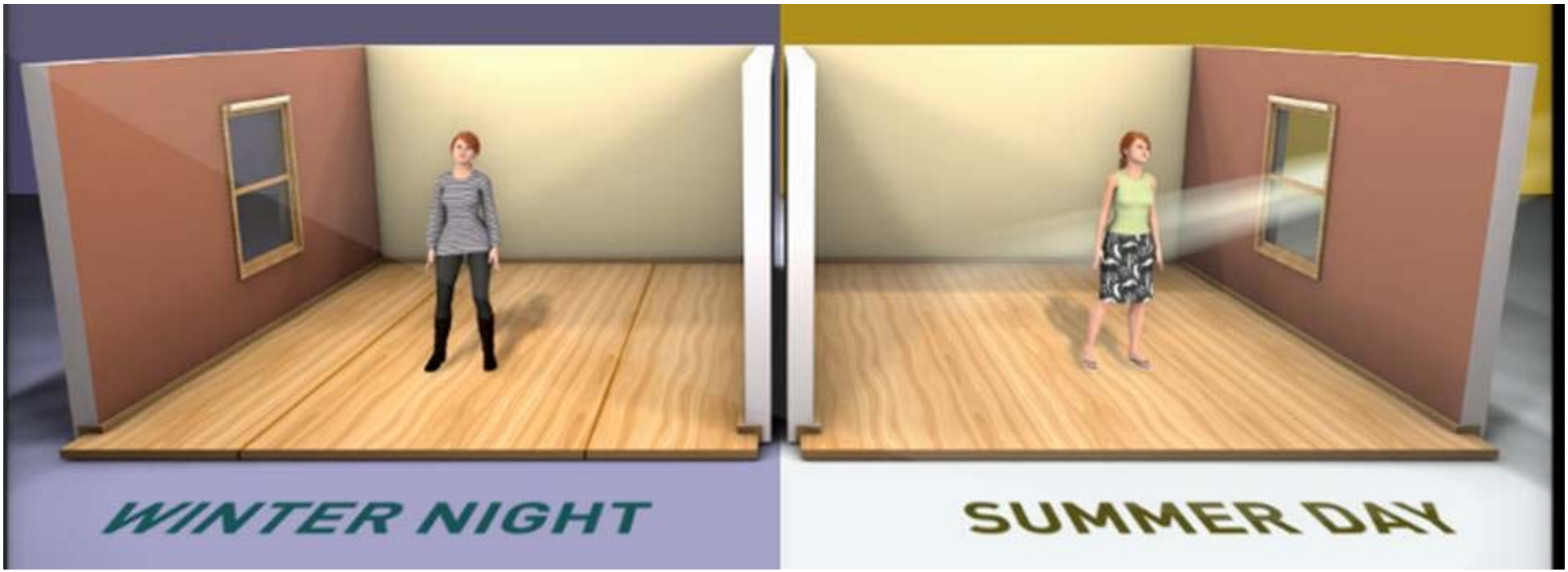
- IF you choose to trade-off on code window performance with high-efficiency HVAC (or lights, water, plug loads) be prepared for homeowner complaints

- As learned in the 1980' beware high solar gain overheat

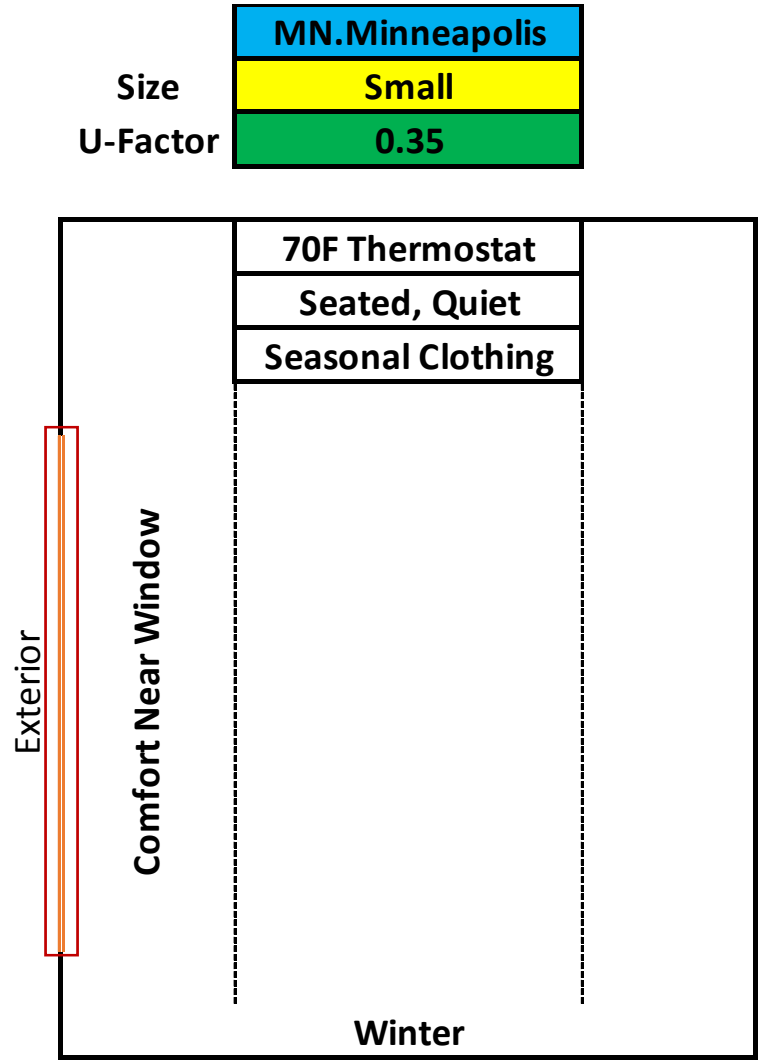
Global Average Area vs. Room

Same comfort in bedroom vs. living room?

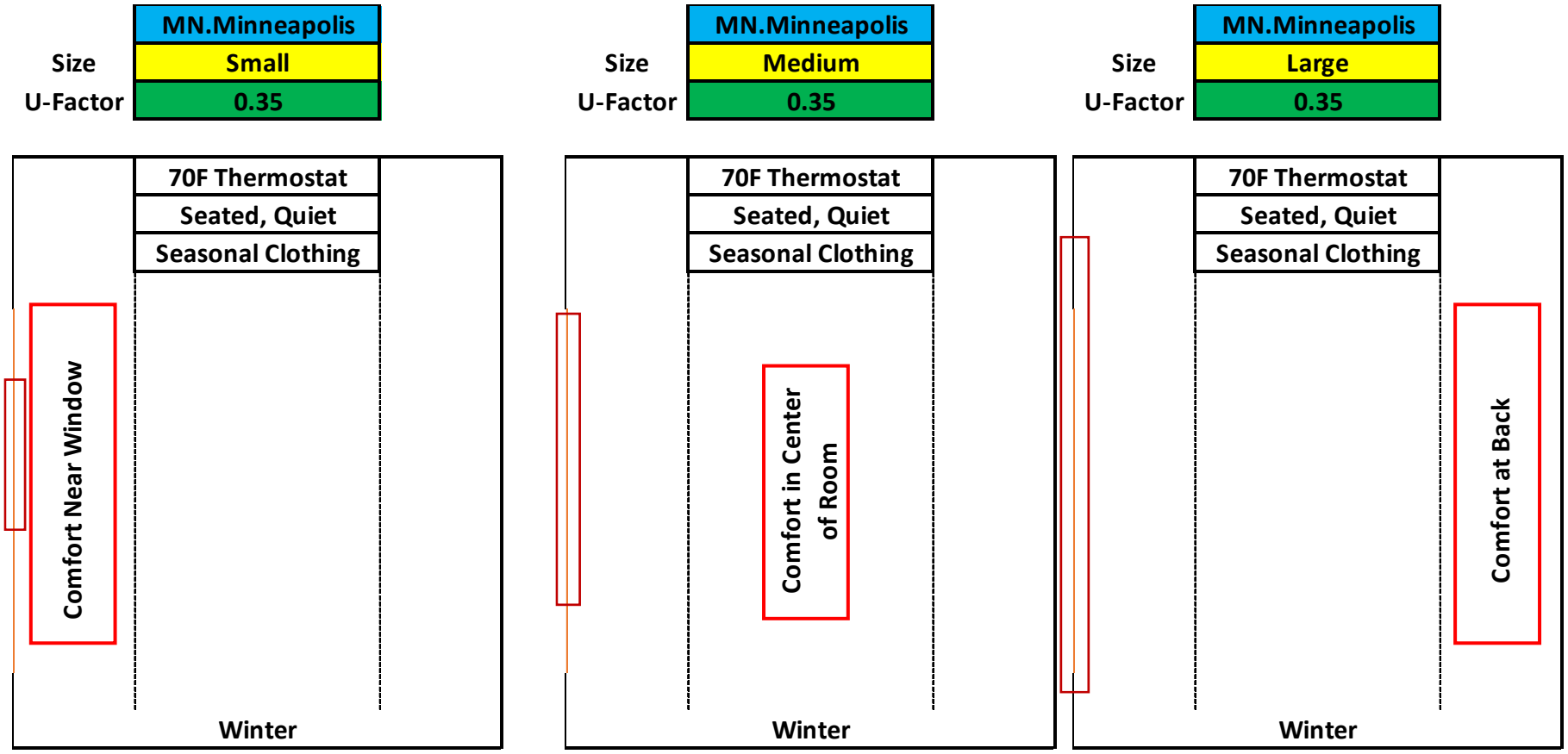
Code and Comfort Implications



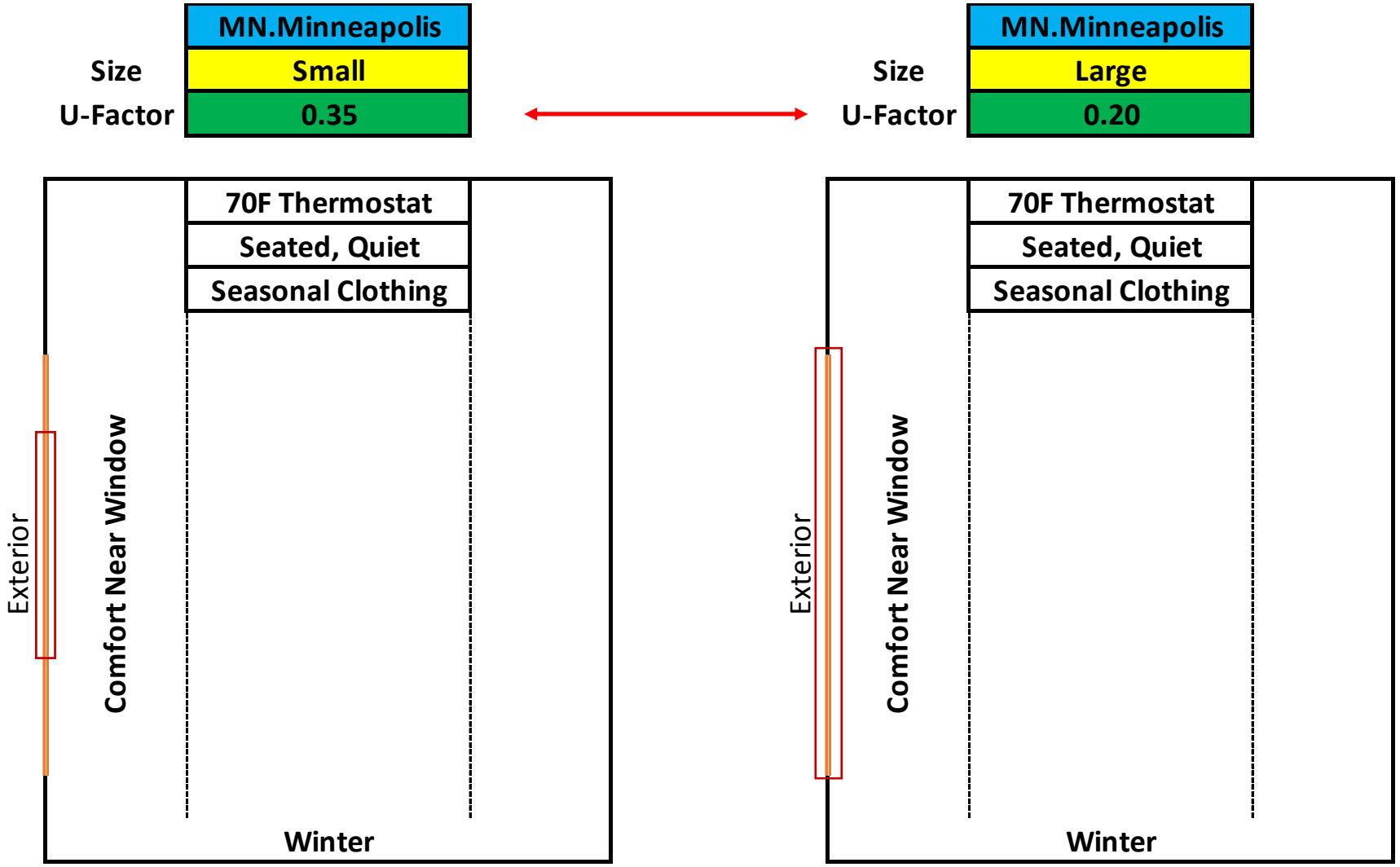
Winter Window Comfort Analysis



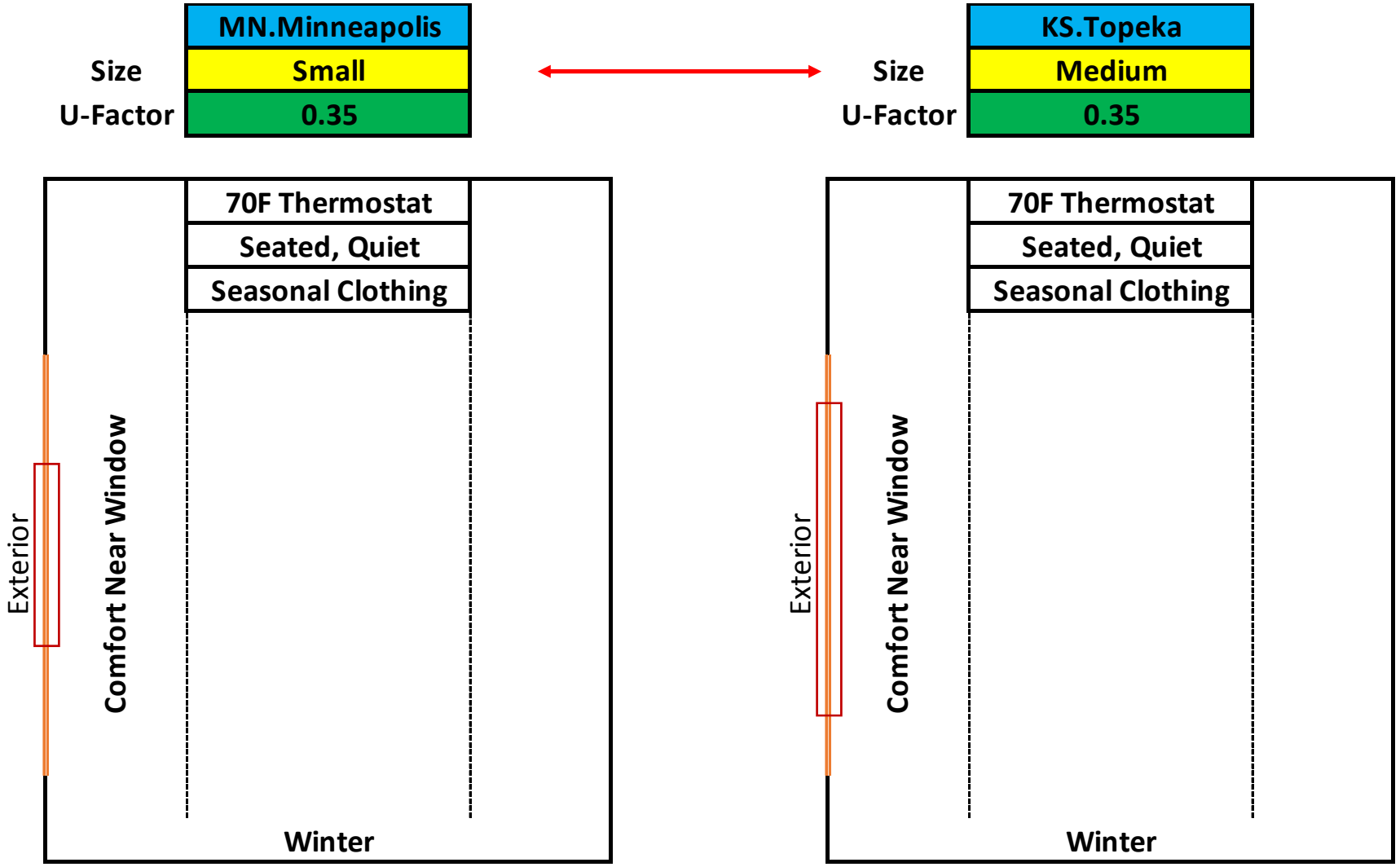
Size Matters!



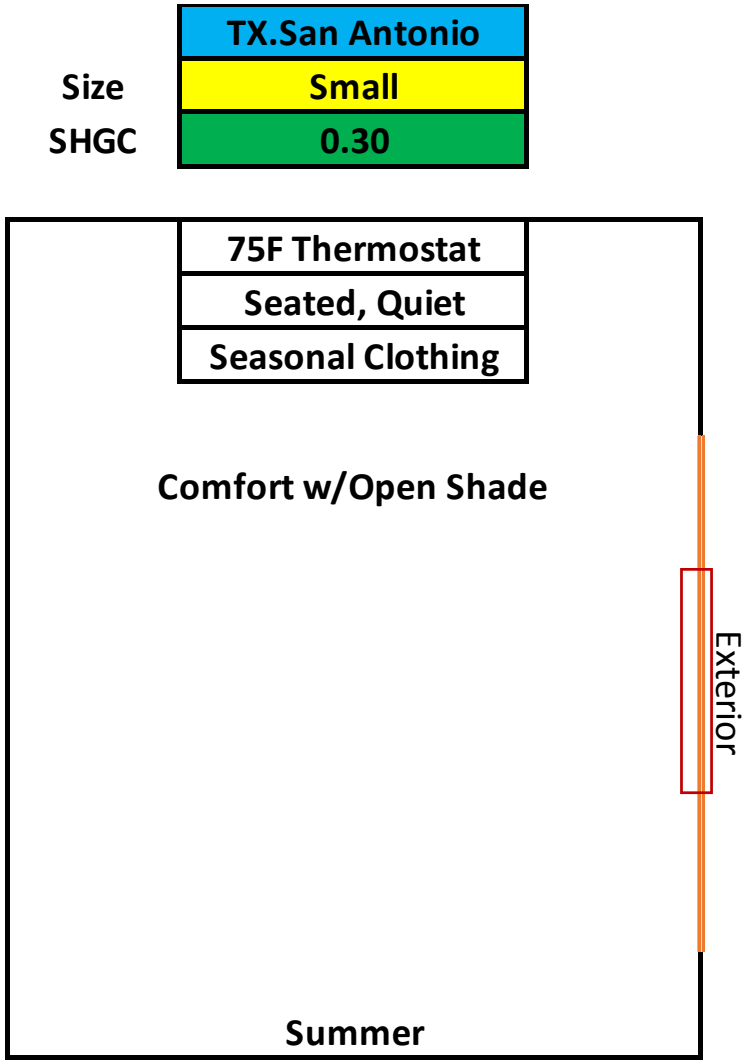
Equal Comfort = Size Specific U



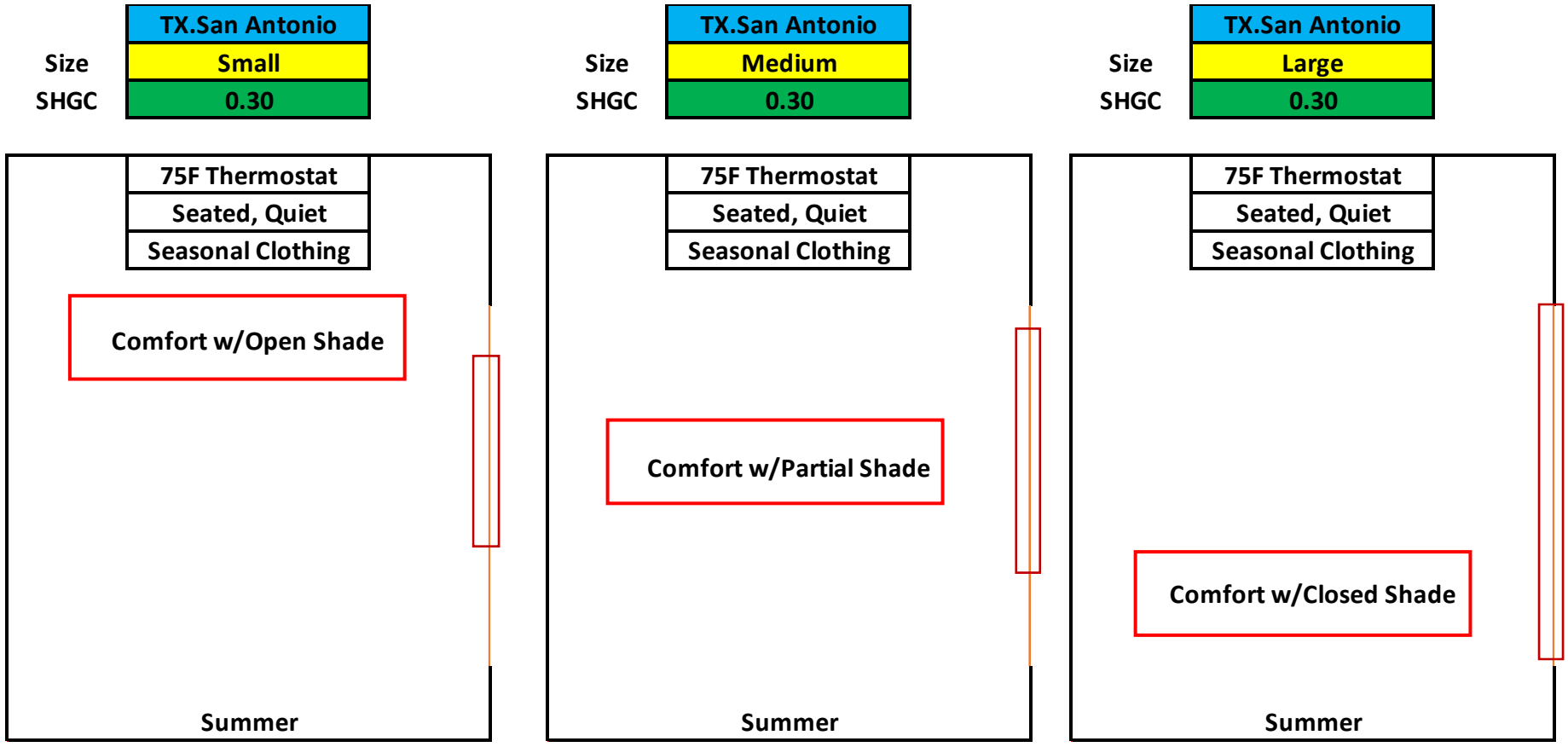
Winter Window Comfort by Climate



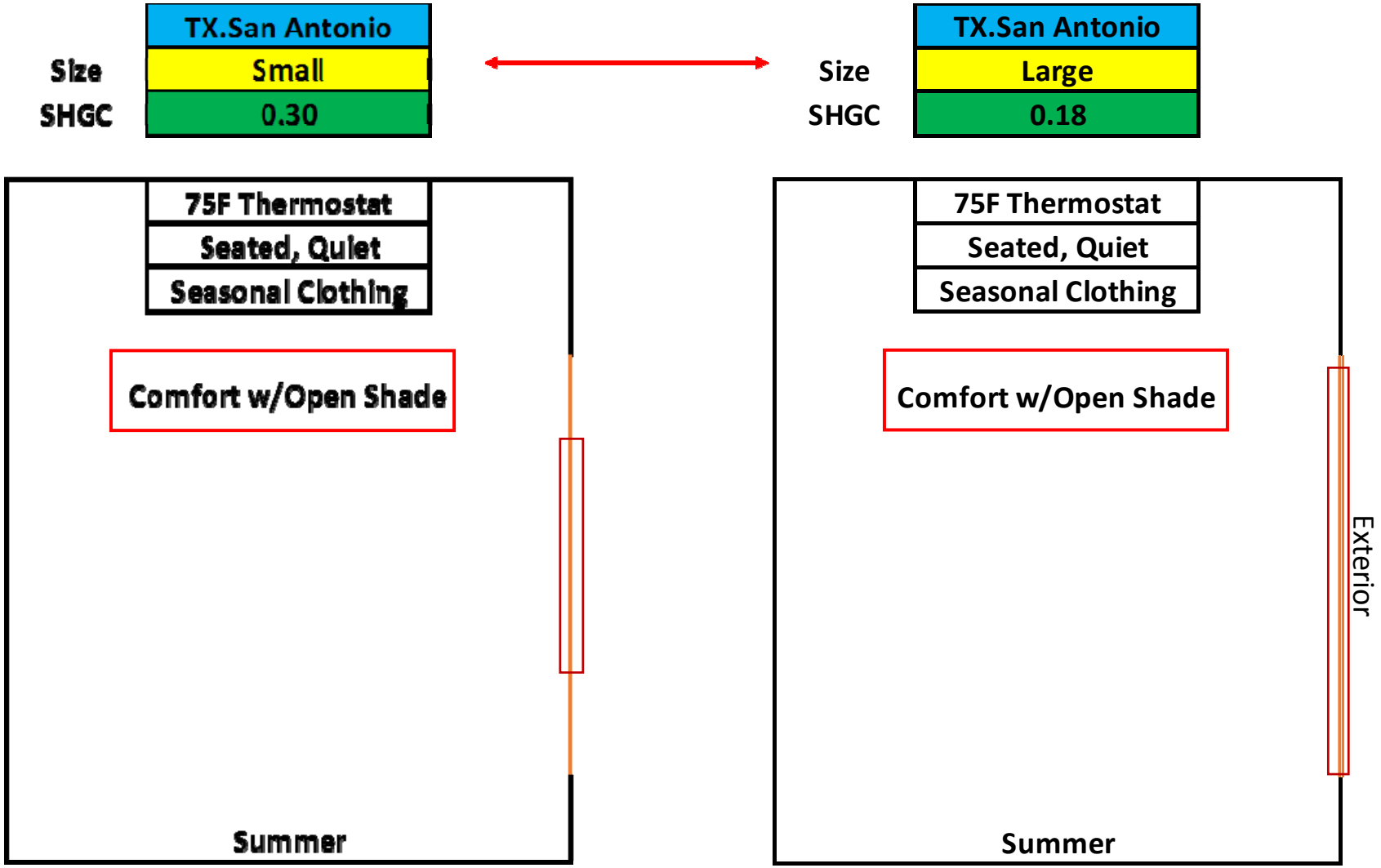
Summer Window Comfort Analysis



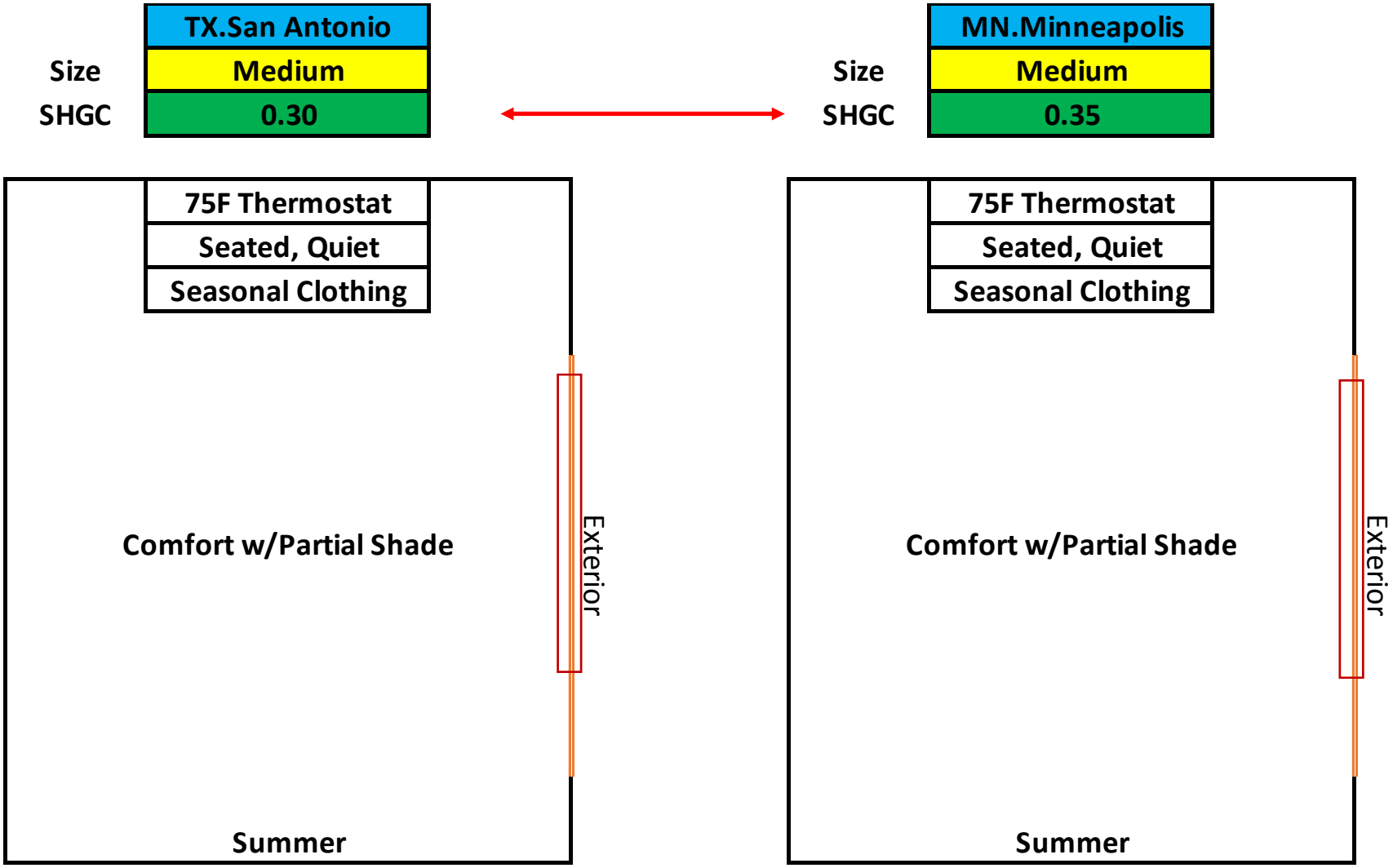
Size Matters!



Equal Comfort = Size Specific SHGC



Summer Climate Effects < Winter



Conclusions

- Windows are not walls
  - Heat loss 5 – 8 times greater adjacent wall
  - Solar gain 20 – 50 times greater than wall

- Use caution when trading away from code defaults.

- Consult customer for their preferences on window area. **BIG** difference in the aesthetics of a space with 15% window area versus 10%.

Future Considerations?

- Remember: We size HVAC systems room by room.
- Will we consider energy use and comfort by room?
- Do we properly quantify the ENERGY IMPACTS OF DISCOMFORT?
  - What happens when people adjust their thermostat?
  - What does this do to our energy use predictions?
  - Is properly considering comfort a for of “Insurance” on our ratings and energy models?

Sometimes the messages are pretty clear…